

**LA-UR-18-31299**

Approved for public release; distribution is unlimited.

Title: Unsupervised Machine Learning for Evaluation of Aging in Explosive  
Pressed Pellets

Author(s): Yeamans, Katelyn Angela

Intended for: UCSD Master's Capstone Project Report

Issued: 2018-12-04

---

**Disclaimer:**

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract 89233218CNA000001. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

# UNSUPERVISED MACHINE LEARNING FOR EVALUATION OF AGING IN EXPLOSIVE PRESSED PELLETS

Katelyn Yeamans

*UCSD Structural Engineering, Fall 2018*

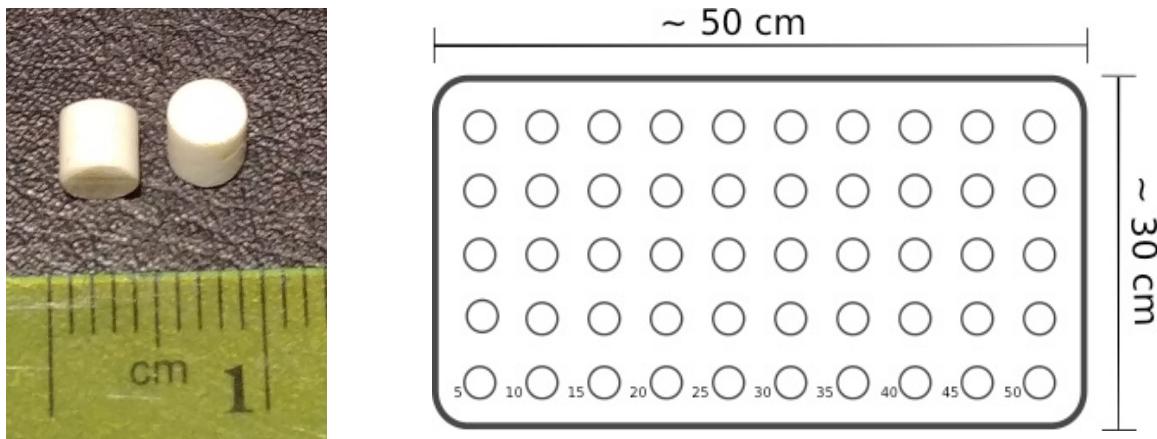
## INTRODUCTION

### *Scope*

This project is an evaluation of the changes in the dimensional geometry of pressed explosive powder pellets when stored for prolonged periods under unmonitored storage conditions. Through the application of Structural Health Monitoring (SHM) techniques, questions to be answered by this investigation are what, if any, effect has the long-term storage of the pellets had on their physical attributes and, if changes have occurred, are the resulting differences of significant magnitude to affect the performance of the pellets. This resulting report includes a summary of the relevant background information, explanation of the SHM approach used to analyze the available data, presentation and discussion of the results, concluding remarks, and an accompanying appendix containing the MATLAB program developed for the project.

### *Pellet Background*

In 2001, a quantity of 200 small pellets of pentaerythritol tetranitrate (PETN) was pressed using industry standards explosive pressing techniques. For each pellet, an operator weighed out a prescribed amount of PETN, funneled the PETN into the pellet mold cavity, and then actuated a mechanical press set to exert a given force onto the pellet mold. Working in a temperature- and humidity-controlled environment, the same operator manufactured each of the 200 pellets, sequentially, using the same mold. After being gently removed from the mold, the pellets were measured for height (in millimeters, mm) and weight (in grams, g), with the diameter determined by the mold cavity. A density (grams per cubic centimeter, g/cc) was calculated for each pellet using the gathered dimensions. The nominal dimensions for the pellets are 3.02 mm in diameter, 3.175 mm in height, and 0.0375 g in weight for a calculated density of 1.65 g/cc. After manufacturing, pellets were packaged in explosive safety storage trays: 50 pellets per tray, each pellet in its own numbered well, and each tray covered by a clear plastic lid. **Figure 1** represents pellet size and shape (simulated material) and the storage tray layout. Each filled tray was placed in a large polyurethane bag with 8 units of desiccant material and a humidity indicator card. The polyurethane bag was double heat sealed at both ends and placed in the storage bunker.



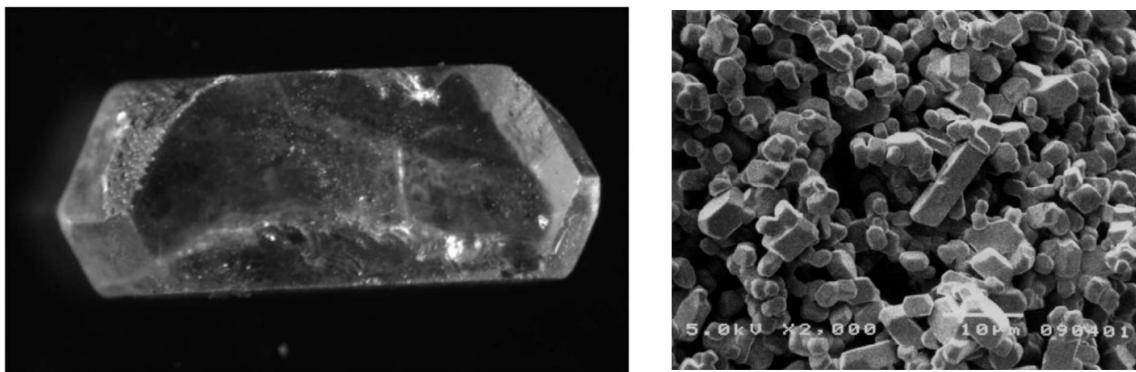
**Figure 1:** Pellet size and shape demonstrated with simulated material (left). Storage tray layout (right); each circle represents a well in which a single pellet is placed.

The temperature and humidity in the storage bunker are neither controlled nor recorded. The bunker facilities are partially buried, providing some insulation from the ambient outdoor temperatures of an arid high desert climate. Based on the low temperature of -23°C and high temperature of 35.6°C recorded between 2007 and 2018 for nearest weather station [1], a conservative temperature range of -26°C and 43°C is assumed for the purposes of this investigation. The humidity control requirement for pellet manufacturing and packaging is an ambient condition of  $25 \pm 2.5^{\circ}\text{C}$  and less than 15% relative humidity; the amount of desiccant added is calculated to maintain the required humidity condition within the sealed volume of the polyurethane bag for an unspecified length of time. There is no minimum requirement for relative humidity, and because the trays are sealed and desiccated, the humidity variations within the storage bunker have not been considered to influence the condition of the pellets.

To collect data for this evaluation, a single tray of the pellets was removed from the bunker after over a decade of storage and the pellets re-measured for height and weight using identical methods to those employed during the original evaluation. An additional measurement was added to collect the diameter of each pellet so that the pellet density could be re-calculated. Although the specific measurement tools and data collection operator changed, the calibration requirements and standard operating procedures for the use of the measurement equipment were unchanged between the initial measurement and the more recent measurement. Before the polyurethane bag was breached to access the pellets for re-measuring, the humidity indicator card was verified to indicate a relative humidity within the sealed environment of less than 15%. The pellets were stabilized for at least 24 hours under environmental conditions matching the original manufacturing conditions before the second set of measurements were taken.

## PETN Properties

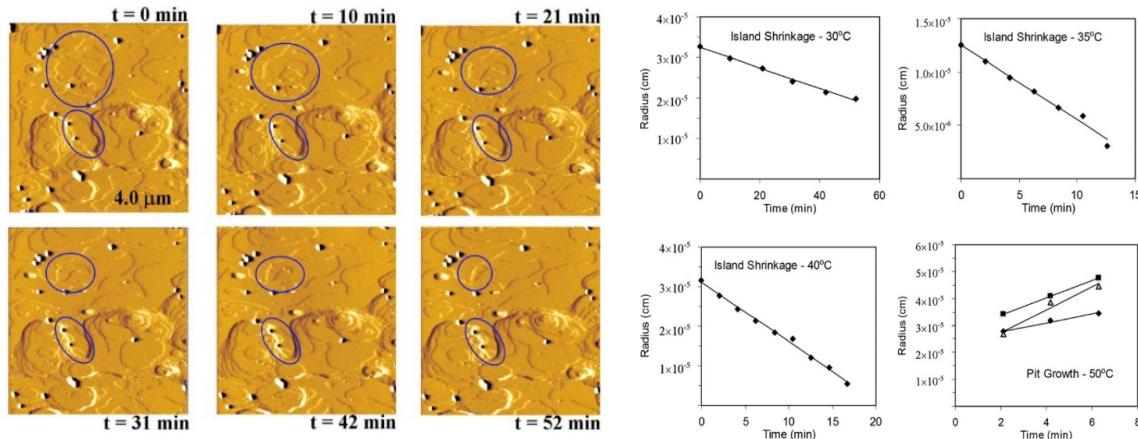
PETN is an explosive compound with the chemical formula C<sub>5</sub>H<sub>8</sub>N<sub>4</sub>O<sub>12</sub>. Single crystals are opaque white in appearance, which under typical compounding conditions, form into tetragonal rods with apex angles [2, 5]. Evolution at higher temperatures produces longer needle-like crystals, and lower temperature produce shorter, more sphere-like crystals [5]. The chemical reagents are usually combined then stored in an aqueous solution until the product is needed, at which time it is crystallized in acetone at a temperature of approximately 22°C [2]. PETN can be used as loosely packed crystalline powder, or pressed into pellet form [5]. **Figure 2** illustrates a typical crystal of PETN and its microcrystalline structure.



**Figure 2:** PETN crystal (right) and microcrystalline structure (left). [2, 3]

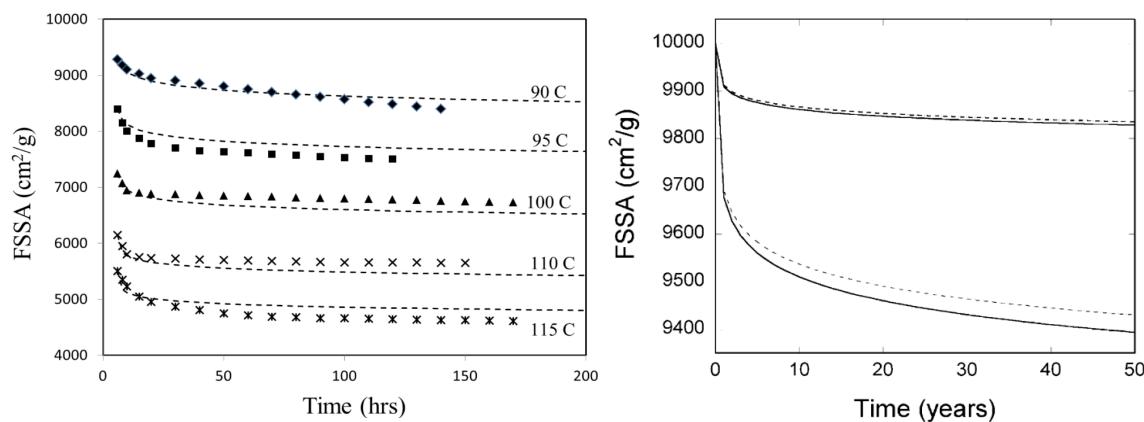
In either loose or pressed form, storage and exposure conditions affect the dissolution and recrystallization of the PETN material, resulting in changes to performance properties [4]. The melting temperature of PETN is 141°C, with a useful service temperature range defined as 70°C to 75°C. [5]. There are two uniquely identifiable phase states of PETN in each PETN crystal, Phase I and Phase II, but Phase II constitutes less than 1% of the formulation at any time under any storage or performance conditions and is not considered to have any effect on the overall performance of PETN [5]. The homogeneity of form and crystalline symmetry makes PETN a reliable explosive for numerous applications [2, 5].

PETN is considered “mobile” on the crystal surface, meaning that under storage conditions above approximately 20°C the surface area of crystals (arranged as single, loose [3] or pressed [5]) is subject to change. Rather than reagent evaporation that frequently occurs in other compounds, crystalline morphology in PETN is based on “re-organization”: wherein the crystal surface tends to get smoother after prolonged periods, as demonstrated by the images and plots in **Figure 3**. This characteristic results in a reduction in crystal surface area of up to 1.8% after a period of one year when stored at 30°C [3]. The smoothing process is referred to as Oswald ripening or sintering, and its effects are observed regardless of storage conditions [5].



**Figure 3:** PETN crystal surface changes (left) and quantified changes in identifiable surface features (right). [2]

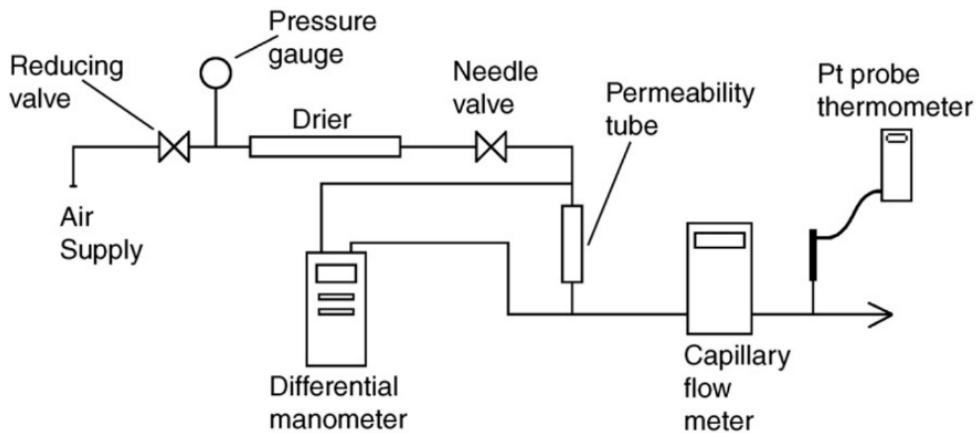
Research on loosely packed crystals concludes that the maximum effect of Oswald ripening on the change in the surface area occurs within the first 70 hours of storage at an elevated temperature of 100°C, with little change from that time until the continuous monitoring was concluded at 816 elapsed hours, or at a follow-up measurement after 18 months [5]. An additional experiment used storage at elevated temperatures for prolonged durations to extrapolate surface area changes expected after decades in storage [8, 9]. Initially, the researchers concluded an approximately 4% decrease in surface area over 50 years when stored at 25°C [8], but re-evaluation of the experimental techniques and analysis capabilities yielded a predicted decrease in surface area over 50 years of 36% when stored at 25°C to 60°C, although the researchers noted that more samples would need to be processed to validate the results of the second study [8]. Examples of surface area trends are included in **Figure 4**.



**Figure 4:** Changes in Fisher Sub-sieve Surface Area (FSSA) at given temperature over hours (left) and initial (top line) and updated (bottom line) predictions for decreased FSSA over decades (right). [5,8]

Some of the challenges in studying PETN are related to the difficulty in finding a method of experimentation that does not affect the measurement outcome, and finding

a numerical modeling method that accurately represents the empirically derived data. Thermogravimetry (TGA) [3], atomic force microscopy (AFM) [3], and air permiametry [4] are the current techniques employed to measure PETN bulk characteristics. TGA isothermally heats single crystals to temperatures between 110-120°C and measures the rate of mass loss, while AFM heats a crystal from 25°C to 50°C and collects images of the crystal surface as the temperature changes [3]. These two methods are problematic in that they actively and quickly heat the PETN to record changes, thereby forcing changes to occur outside of actual operational or storage parameters [3]. For analysis by air permiametry, samples are packed into the end-use bodies by centripetal force then air is passed through the packed sample with a resulting measurement of pressure loss across the sample volume [4]. A simple schematic of the experimental setup for PETN analysis via air permiametry is included as **Figure 5**. The pressure drop correlates to the permeability of the PETN sample, which is then related to the particle Fisher Sub-sieve Surface Area (FSSA) within the sample [4]. Although the air permiametry technique maintains the thermal integrity of the PETN material from its initial precipitate state, it relies on the powdered form of the material not being used at high densities.

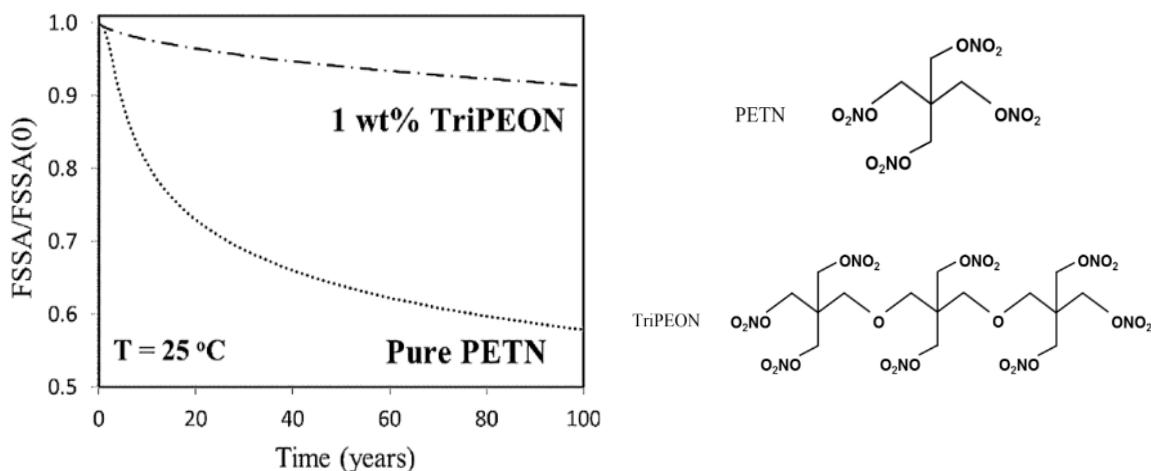


**Figure 5:** Simple schematic of air permiametry experimental setup. [3]

For the purpose of the pellets used in this experiment, measurement techniques employing destructive, thermally destabilizing methods such as TGA and AFM at temperatures exceeding the worst-case storage temperature conditions will not provide a reliable model applicable for post-storage use potential [3], and air permiametry techniques cannot suitably model the surface area changes of high-density samples [4].

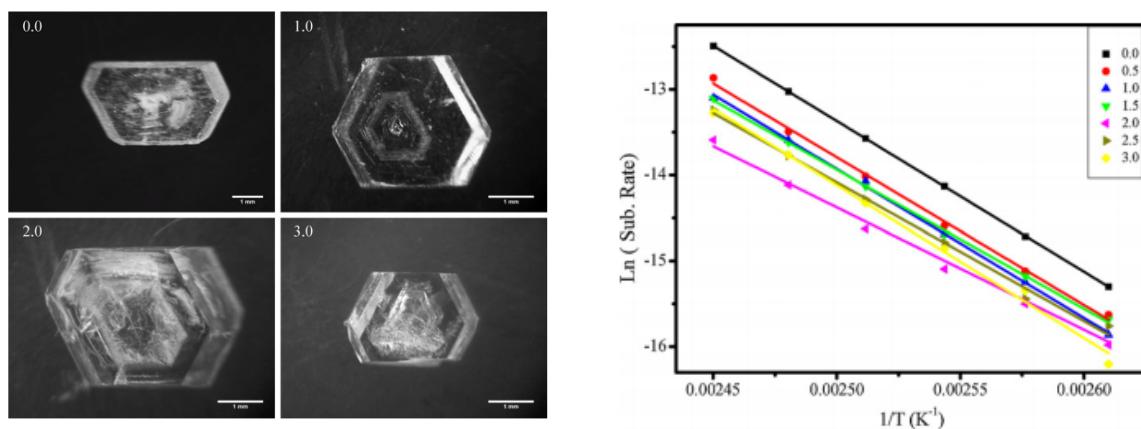
Some researchers have shown that the effects of Oswald ripening and temperature excursions on the surface area of PETN can be mitigated slightly using doping, surface agent, or heat treatment techniques, as seen in the plot of **Figure 6**. Increasing the percentage quantity of the naturally occurring impurity homologue

tripentaerythritol octanitrate (TriPEON) to only 1% showed a significant decrease in the desorption rate of the PETN, proving this as a “mild binder” for the material [5].



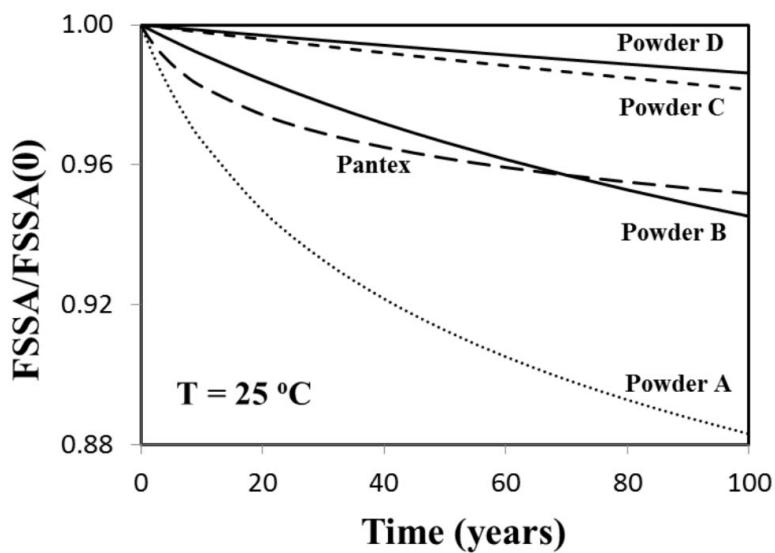
**Figure 6:** Reduction in change of FSSA with TriPEON doping (left) and molecular structures of PETN (top right) and TriPEON (bottom right). [4, 8]

Success in reducing surface area mobility has also been observed when the PETN synthesis process is precipitated in water, because the water blocks crystallization sites that may have hosted more fractured or “kinked” PETN molecules [5]. Polymer materials such as polysaccharide or wetting agents can also be used to retard the sublimation of PETN during high temperature exposure, acting in a similar manner to the homologue dope by linking to and saturating any kinked PETN molecules on the surface of the crystal [6]. Examples of the reduction in sublimation for PETN doped with deionized water are illustrated by **Figure 7**.



**Figure 7:** Images of PETN crystals when doped with differing ratios of water (left) and quantifiable reductions in reagent sublimation rates as a result of various water doping ratios (right). [5]

Additionally, promising results in stabilizing PETN are noticed when the material is thermally cycled or “pre-heated”, with no significant change in surface area measurements noticed after approximately 600 days following an 8 hour annealing process at 240°C [5] or after 100 hours at 70°C for homologue-doped samples [8]. **Figure 8** below illustrates these results, with Powder A, Powder B, and Pantex being non-thermally cycled PETN samples and Powders C and D having undergone different thermal cycling treatments. While these studies shed light on actions that can be taken to prepare PETN for long-term storage, they are mostly focused on the reduction of surface area mobility, which, while closely related to performance, has not been directly correlated to the detonation performance of PETN at the end of the studies.



**Figure 8:** Changes in FSSA for typical PETN and thermally treated PETN. [5]

Numerous references such as the studies discussed above are available regarding loose crystalline PETN, but finding information on specialized uses of PETN in molded pellet form is more difficult, especially for PETN pressed to near theoretical maximum density (TMD). When powdered PETN is compressed to a calculated density such that the density of the pressed form is as close as theoretically possible to the density of an individual crystal of PETN, that pressed form is said to be at TMD [5]. The density to which PETN is pressed into a form affects the explosive performance parameters, such as initiation temperature and deflagration rate [3]. The pellets in question for this experiment are pressed very near to the TMD value for PETN, and as such, density becomes the most important parameter by which the pellets can be evaluated [9]. One study of low density pellet data collected at lower temperatures for approximately 300 days extrapolated a maximum recommended storage temperature for pressed PETN not to exceed 49°C at the risk of significant changes to the initiation

sensitivity of pellets pressed at lower densities [7]. This theoretical recommended maximum temperature is very near to the maximum of the assumed actual temperature range of the specific pellets used in this evaluation, supporting the need for an investigation into the current condition of the stored pellets.

## **SHM METHODOLOGY**

What is known about the high molecular mobility of PETN indicates that some change to the pellets is expected after a storage period even as little as 70 days, but it is unknown to what extent these micro-scale changes can have on a high density bulk PETN material, i.e., to what extent, if any, have the molecular changes resulting from prolonged storage have changed the overall physical dimensions of the pellets. This project approaches the inherent statistical pattern recognition issue of evaluating changes to the pellets using SHM definitions and methodology. Some parameters of the project, such as the data acquisition portion, were limited by the allowable methods for explosives handling and were completed by trained, competent operators.

### *Operational Evaluation and Environmental Effects*

There are several life-safety and economic justifications for performing SHM of the prolonged storage of PETN pellets in uncontrolled conditions. Pellets with changes in shape are unlikely to perform as required, either due to density value changes within the explosive or failure to fit next level assembly caused by changes in physical geometry. If the pellets are not the correct density, they will be unusable, and if the pellets are submitted for use and do not perform as expected, the results of costly experiments will be deemed unacceptable. Changes to the structural integrity of the pellets may also cause the PETN to behave in an unpredictable manner, making it a safety hazard during handling and storage. If there is no statistically significant change in the pellets after the long storage duration, an economic benefit may be gained by pressing pellets when other production demands are low and resources are readily available.

Damage to the pellets that would negate their usability is defined as changes to the physical dimensions of the pellets as a result of prolonged storage to an extent that the calculated density is fundamentally changed or the pellet exceeds tolerable part geometry. Of the two damage possibilities, changes to the density of the pellets are the most concerning.

Defining the functional conditions for this study is complicated, both for the operational and the environmental settings. The physical traits of the pellets are evaluated in a temperature and humidity controlled environment, but stored in non-controlled, non-monitored bunkers with only desiccant packets within the sealed

volume of the packaged tray to moderate humidity conditions. Because the actual operation of the pellets results in their destruction, the operational functional conditions for the purpose of this investigation are defined as the pellet in an unrestrained resting state within its individual compartment of the standard storage tray. Monitoring is focused on this “operational condition” of the pellets and is mostly affected by the bunker storage conditions; these conditions also define the environmental functional conditions. For safety reasons, the pellets were removed from the operational condition to a controlled environment for data collection.

Data acquisition in the operational environment of the storage bunker itself is restricted by several factors. Power supply to the storage bunkers is limited, and because the pellets are made from PETN, care must be taken to minimize their exposure to electrical current, shock or impact loading, and extreme high temperatures. Access to the storage areas is also regulated to approved personnel only, and computational devices are strictly prohibited. The bunkers themselves have no environmental monitoring systems, so it is not possible to correlate the environmental conditions to the operational condition of the pellets.

### *Data Acquisition & Normalization*

The data acquisition portion of this project was completed using approved methods and instruments for the safe handling and manipulation of explosive materials. For the initial measurements the mold used to form the pellets controlled the diameter, with the height of the pellet measured by an indicator-over-base and a high accuracy scale used to collect the weight of the pellet. An indicator-over-base and scale calibrated to the same specification as the tool used for the initial measurements was used to measure the height and weight of the pellets for the updated data set. A micrometer was used to measure the diameter of the pellets for the updated data collection, because re-inserting the pellets into the mold would only provide go/no go results and posed a high risk of damage to the pellets. All data was recorded by hand into an Excel workbook. MATLAB was used to process the data. Methods such as TGA, AFM, or air permiametry used to evaluate raw crystalline PETN were not considered as data collection techniques due to their destructive nature, as is the case for TGA and AFM, or because, like air permiametry, they are unsuitable for measuring pressed pellets [6]. As mentioned previously, the exact storage conditions for the pellets are not tracked, which makes data normalization relative to the bunker environment impossible.

### *Features & Damage Detection*

The scope of this investigation limits the potential feature identification to those that may be determined from the data that has been collected for all 200 pellets at the

time of initial manufacturing and the updated data for the 50 pellets from Tray 1 only. From 200 previous and 50 new data points, the feature of physical change in these parameters must be extracted. Damage will be defined as either significant variation in the shape of a pellet from the initial measurement to the updated data point or statistically significant changes to the calculated density of a pellet.

### *Statistical Model Development*

Because the state of the pellets is either “good” or “outlier” for the initial measurements and “unknown” for the subsequent re-measurements, and because novelty detection is the primary intention of this investigation, the basis for the initial statistical model development will be a cluster-based unsupervised learning model [10]. Machine sorting will be performed on both sets of data. The intent is to sort the initial data for identification of outliers then re-sort the data including the updated measurements to identify any possible additional outliers resulting from extended storage.

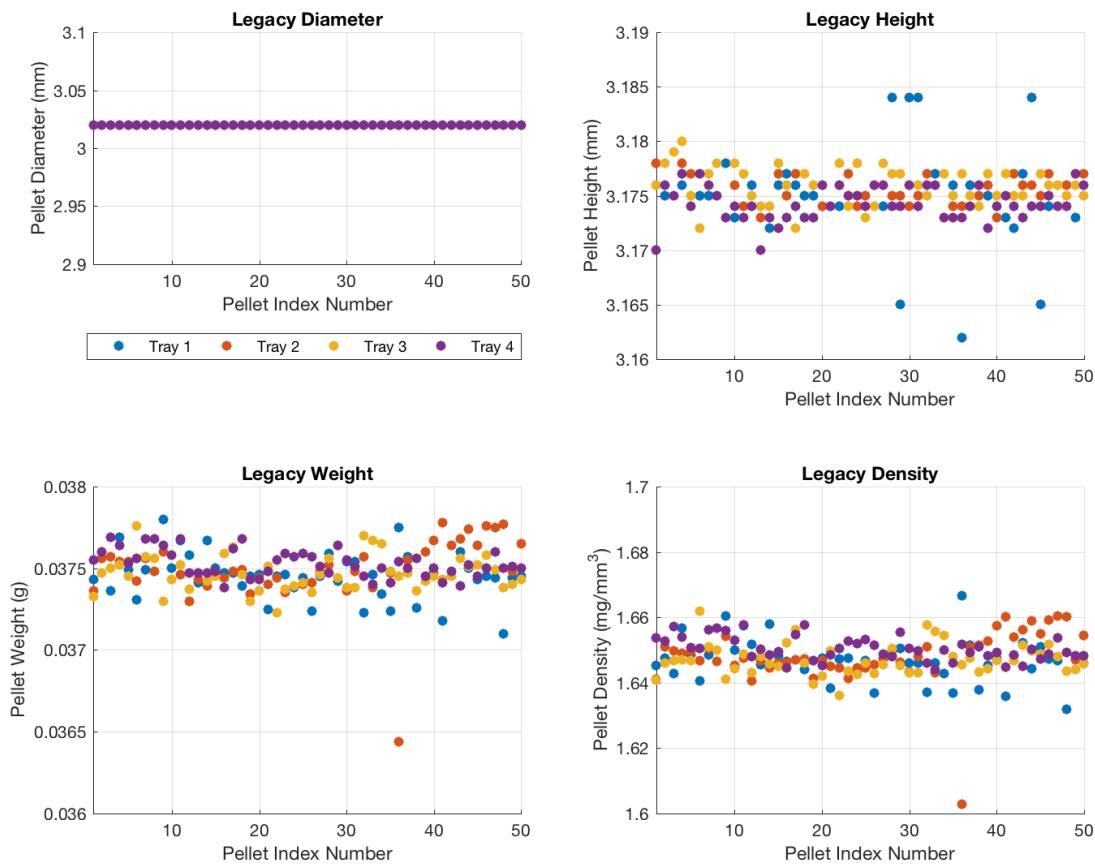
## **SHM APPLICATION**

### *Data Indexing and Statistical Evaluation*

Each individual pellet is indexed by tray number (1 through 4) and by its position within that tray (1 through 50), e.g., pellet 3-47 is the forty-seventh pellet in Tray 3. The sequence of production follows increasing tray and position numbers; for example, pellet 1-1 is the first pellet produced, 2-44 is the ninety-fourth pellet produced, 3-15 the 115<sup>th</sup>, and pellet 4-50 the 200<sup>th</sup> pellet. For data sets where the entire population of pellets is considered, the individual pellets are identified by this manufacturing sequence value (1 through 200). The data collected at the time of manufacturing is referred to as the “Legacy” data, and plots or charts with Legacy in the title represent the initial values (by tray or total population) for each pellet. The MATLAB code included in the Appendix of this document was used for all numerical analysis, machine sorting, and data plotting.

The raw values of Legacy measurements for pellet diameter (OD), pellet height (H), and weight (W) as well as calculated density (D) are collected in **Figure 9** below. Note that the value of OD for all pellets across all trays is identical, as this value was assumed to be the measured diameter of the press mold (3.02 mm). Tray 1 shows the broadest range for all measured and calculated Legacy values, with pellets 1-28, 1-30, 1-31, and 1-44 exhibiting significantly above average heights and 1-29, 1-36, and 1-45 below average height; and lower W values for pellet 1-48. These variations in the geometric properties of Tray 1 pellets result in lower than average calculated D values

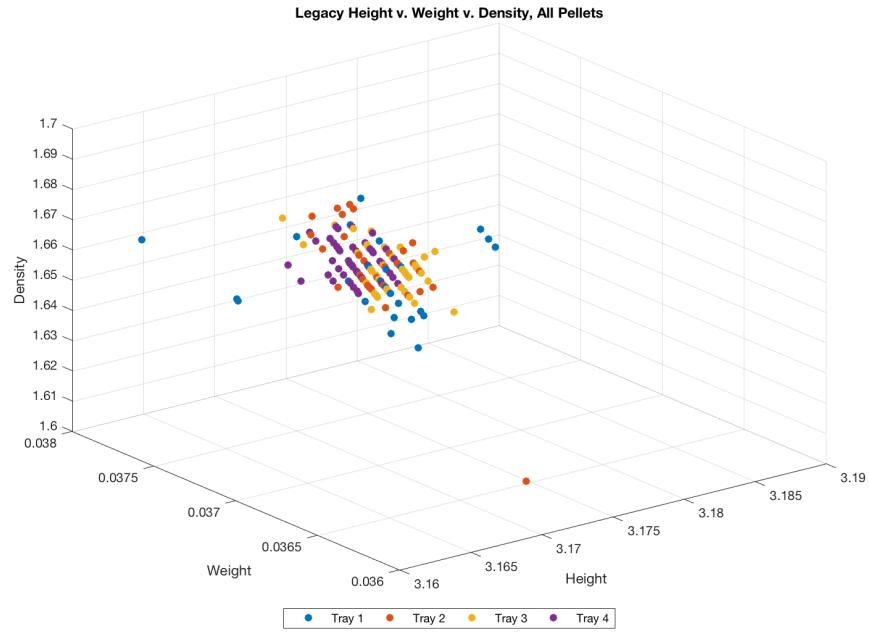
for the 1-48 pellet, and higher than average D for pellet 1-36. Because Tray 1 represents the first 50 pellets run, it is expected to see greater variance as the manufacturing setup and processes hone into optimal settings. No correlation between pellets of the same index across trays is expected, because each pellet is manufactured on an individual basis. Significantly underweight pellet 2-36 is also identifiable, and this condition corresponds to the very low D value for the same pellet. The data points identified as outliers in the raw data from Tray 1 have been included in all statistical and sorting operations; these pellets will provide “markers” throughout the course of the analysis, especially during machine sorting.



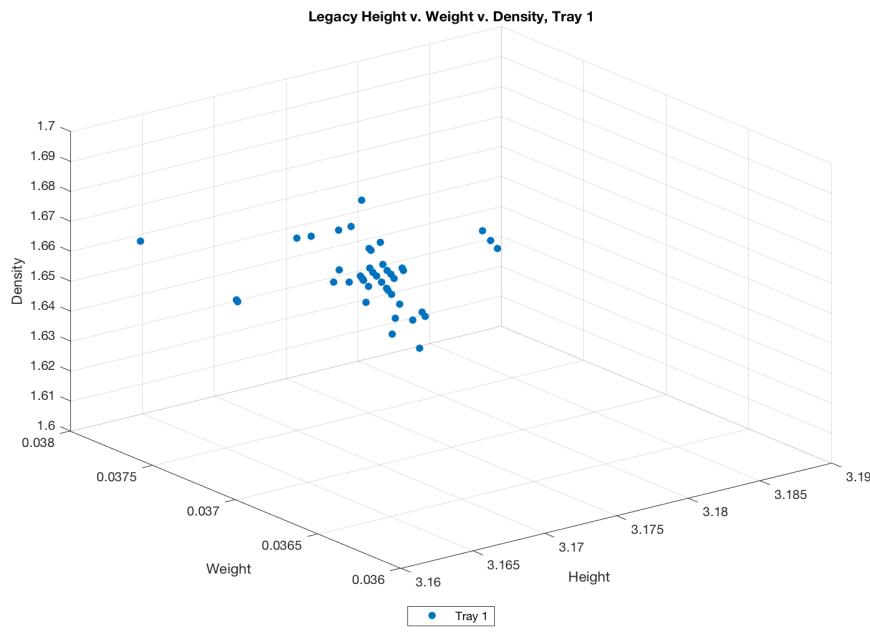
**Figure 9:** Legacy values for all geometric parameters, by tray. Color legend for Legacy Diameter plot applies for all plots in this figure.

**Figure 10** arranges the Legacy data by tray with the H, W, and D values acting as axis. Although the OD values are available and plotting the H and W values against OD would visually represent the D value for each pellet, OD was not included because it is uniform and does not represent a controllable variable for manufacturing. An

unanticipated advantage of this experiment is having the majority of the population outliers in Tray 1, as this is the only tray for which “Updated” measurement data is available: if the outlier pellets exhibit significant changes due to prolonged storage, it may be an indication of more minute changes in the more homogenous population. **Figure 11** shows the values for Tray 1 pellets isolated from the total population, a plot that will be helpful for comparison when the updated data is included.



**Figure 10:** Legacy data for all pellets, by tray.



**Figure 11:** Legacy Tray 1 data.

Histograms and statistical properties including the mean, standard deviation, median, mode, minimum, and maximum values for the data were also collated by tray and for the total population. The same evaluations were performed for each of the Legacy trays, but because the interest of this investigation focuses on the data from Tray 1 and the total population, only those plots will be presented in the body of this report. Plots and tabulated data for Trays 2-4 can be found in the Appendix. **Table 1** represents the statistical values for Legacy Tray 1 measurements, and **Table 2** captures this information for the total Legacy pellet population.

**Table 1: Statistical Properties of Legacy Pellets, Tray 1**

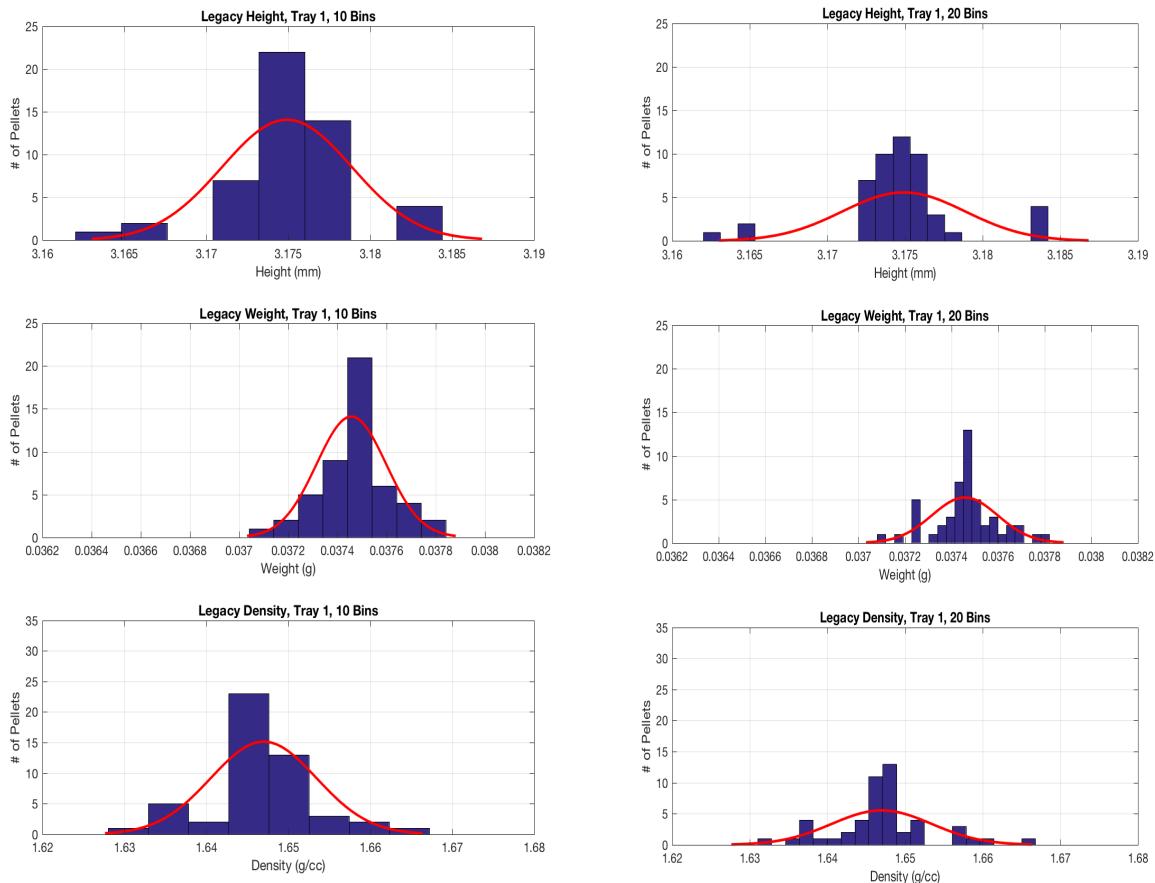
Parameter	Outer Diameter (mm)	Height (mm)	Weight (g)	Density (g/cc)
<b>Mean</b>	3.020	3.175	0.0375	1.65
<b>Standard Deviation</b>	0	0.00397	0.000141	0.00645
<b>Mode</b>	3.020	3.175	0.0375	1.65
<b>Median</b>	3.020	3.175	0.0375	1.65
<b>Minimum</b>	3.020	3.162	0.0371	1.63
<b>Maximum</b>	3.020	3.184	0.0378	1.67

**Table 2: Statistical Properties of Legacy Pellets, Total Population**

Parameter	Outer Diameter (mm)	Height (mm)	Weight (g)	Density (g/cc)
<b>Mean</b>	3.020	3.175	0.0375	1.65
<b>Standard Deviation</b>	0	0.00250	0.000140	0.00622
<b>Mode</b>	3.020	3.174	0.0375	1.65
<b>Median</b>	3.020	3.175	0.0375	1.65
<b>Minimum</b>	3.020	3.162	0.0364	1.60
<b>Maximum</b>	3.020	3.184	0.0378	1.67

A histogram with 10 bins (default MATLAB value) was built for the Legacy height, weight, and density as seen for Tray 1 in **Figure 12** and for the total population in **Figure 13**. From this plot common statistical distribution of the data points is not readily identifiable, so the data is re-sorted into twenty bins (2x default bins, as illustrated in

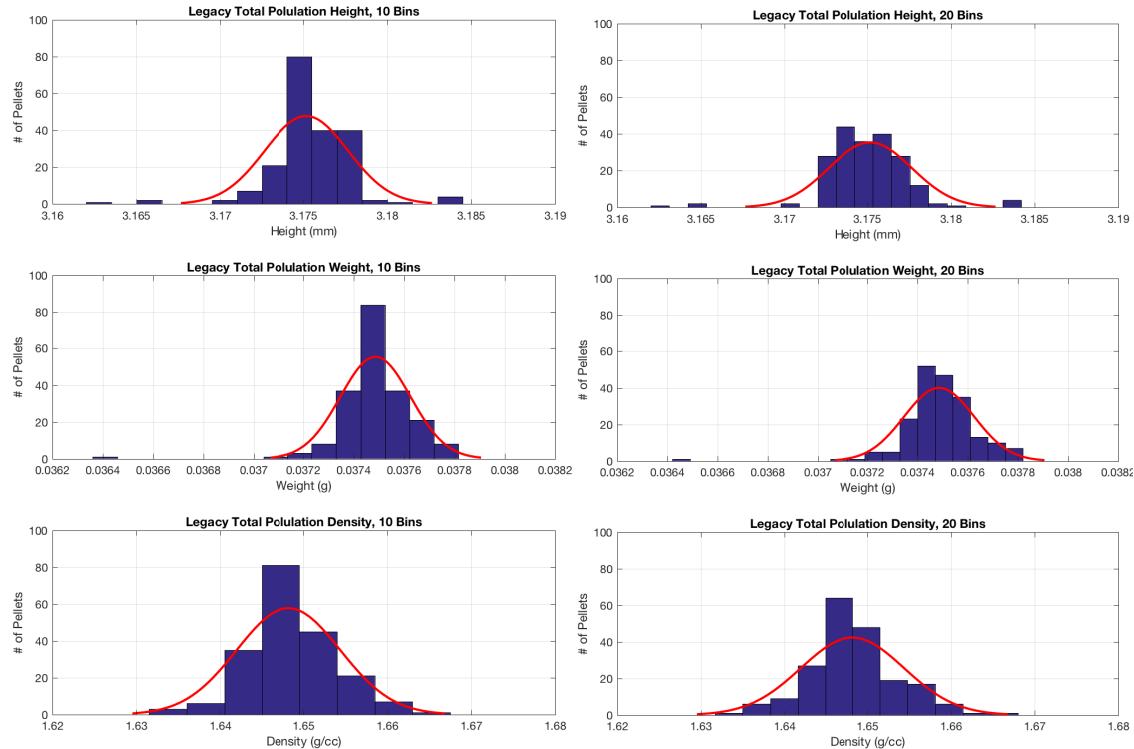
Figure 12 for Tray 1 and Figure 13 for total population) and reevaluated to see if additional bins reveal a previously unseen distribution pattern. Because decreasing the bin size does not immediately reveal a clear characteristic distribution, a chi-squared goodness of fit test is applied to the individual tray data and the combined total population data. As seen in **Table 1**, the null hypothesis that the data fits a normal distribution is rejected for all cases of data except the Legacy W values for Tray 1; however, the 0.05  $p$  value for this test indicates that the acceptance of the null hypothesis (as denoted by a “0” in the Accept/Reject Null Hypothesis cell, rejection is denoted by a “1”) should hold true for 95% of all pellets tested; however, the null hypothesis is rejected for the total population test, and as such, it is likely that the acceptance of the null hypothesis for Tray 1 is an aberration. Because there is absolutely no variance in the OD values for the Legacy data, testing the values accepts null hypothesis but cannot calculate a  $p$  value (because a 100% confidence interval is not considered possible), so  $p$  is declared “not a number” (NaN). The Appendix holds histograms and tabulated results for the Legacy tray data not presented here.



**Figure 12:** Legacy Tray 1 histograms for given parameters organized into 10 bins (left) and 20 bins (right).

**Table 3: Chi-Squared Goodness-of-Fit Testing Results**

Parameter	OD		H		W		D	
Test Case	Tray 1	Total Pop.	Tray 1	Total Pop.	Tray 1	Total Pop.	Tray 1	Total Pop.
Accept/Reject Null Hypothesis	0	0	1	1	0	1	1	1
P Value	NaN	NaN	0.000008	0.001	0.05	0.0007	0.0002	0.001

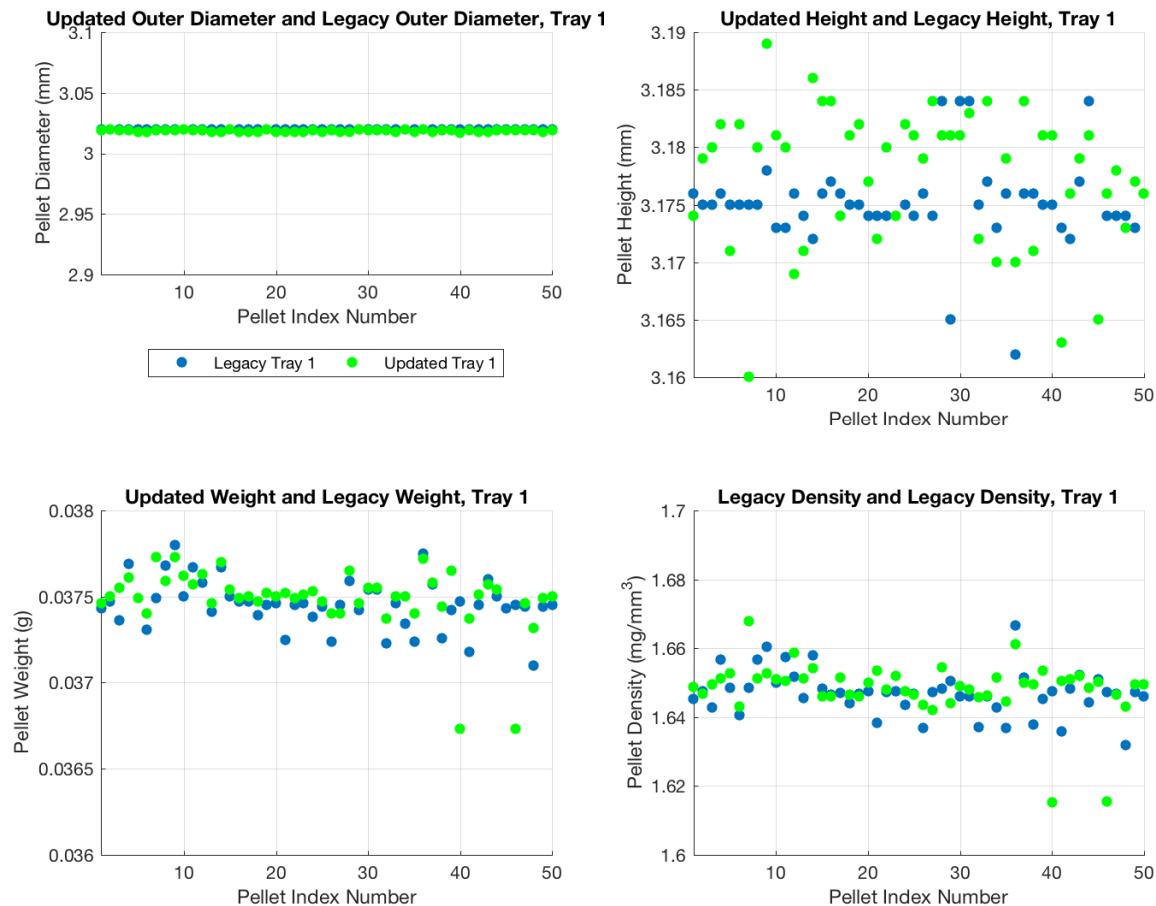


**Figure 13:** Legacy Total Population histograms for given parameters organized into 10 bins (left) and 20 bins (right).

The same set of statistical analysis and distribution tests were performed for the Updated data of Tray 1. **Figure 14** collects the raw measurement data for the OD, H, W, and D values and plots the Updated numbers and the Legacy numbers. Recall that the Updated data is only available for Tray 1, and that the Legacy and Updated data point for each index value represent the measured and calculated values for the same pellet, only years apart. While values for the Updated OD are presented here, any notable variations between the Updated and Legacy points should be interpreted including the caveat that the Legacy OD values were assumed to match the diameter of the press mold and were not directly measured. The Updated OD values were directly measured,

however, and contribute to the calculation of the Updated pellet density, so the influence of any changes is reflected in this parameter.

The largest notable difference between the Updated and Legacy data is seen in the measurement of H. Here it is helpful to recall the index values identified as markers in the Legacy data: 1-28, 1-30, 1-31, and 1-44 for above average height values and 1-29, 1-36, and 1-45 below average. Where these marker points were clear outliers in the Legacy population data, they are barely distinguishable among the Updated H values, and new marker pellets with abnormal H values can be identified as 1-9 and 1-14 on the high sides and 1-7 and 1-41 on the low end. There are now two notable outliers in the Updated W values (pellets 1-40 and 1-45), although neither falls below the marker index 2-36 from the Legacy data. Additionally, the changes in the Updated H and W values are apparent in the Updated D calculations, where the general increase in H has slightly reduced the general Updated D results.



**Figure 14:** Updated and Legacy values for all geometric parameters, by tray. Color legend for Outer Diameter plot applies for all plots in this figure

Updated and Legacy Height v. Weight v. Density, Tray 1

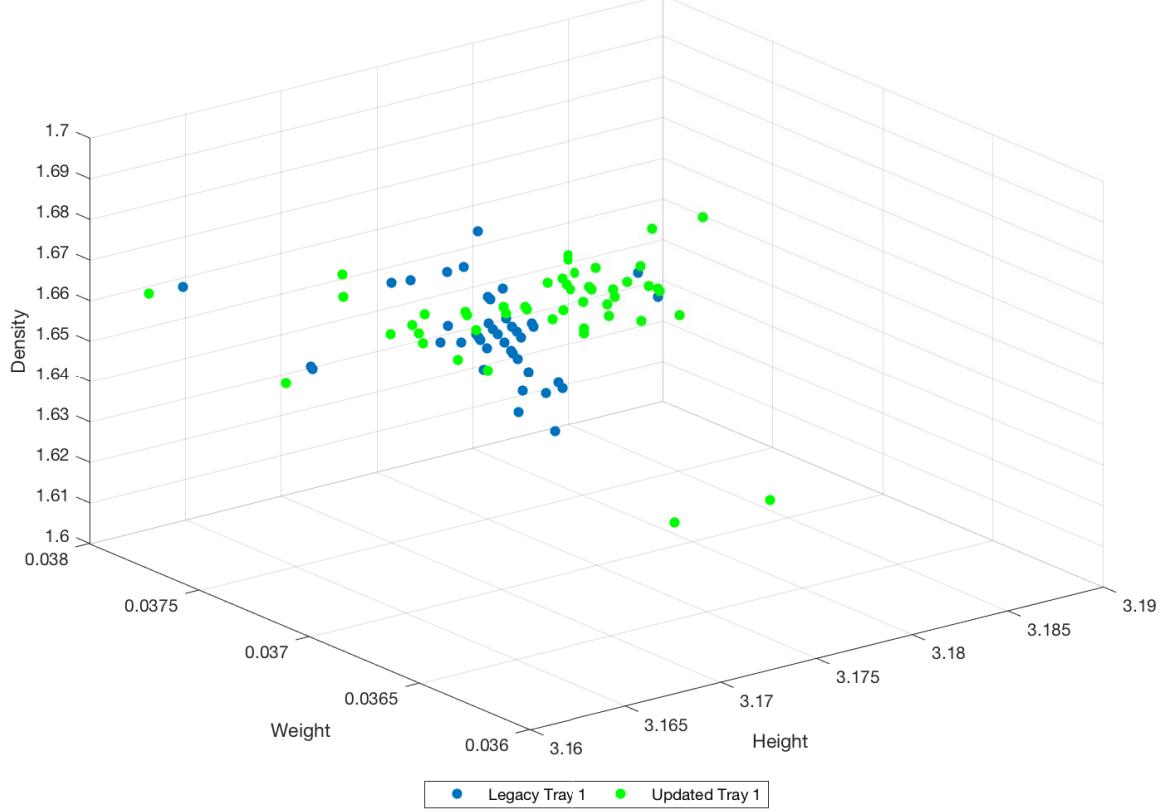


Figure 15: Legacy and Updated data.

The height versus weight versus density scatter plot of **Figure 15** illustrates the similarities in the two datasets for a couple of the marker datum, but also shows that there are corresponding changes for other data points as a result of aging. This scatter plot view of the pellets illustrates the tracking of the Legacy versus Updated values for the low height pellets 1-28 and 1-36 and the identification of the two new low weight pellets 1-40 and 1-45.

**Table 4** represents the statistical values for Updated Tray 1 measurements compared to the Legacy values, and **Table 5** captures this information for the total Updated pellet population alongside the Legacy population numbers. For calculation of the Updated population data, the 50 Updated values for each parameter are added in sequence to the end of the original indices such that Updated Tray 1 values are represented as values 201-250. The decision was made to append the Updated data to the original data to simulate the statistical analysis as though the Updated Tray 1 were actually a Legacy Tray 5. In this manner, the effect of the Legacy measurements on the total Legacy population are retained, and changes to the population statistics with the inclusion of the Updated Tray 1 data reflect the actual changes for each characteristic.

While the mean, median, mode, minimum, and maximum values for each parameter change very little between the Legacy and Updated values, noticeable

changes are evident in the standard deviation values. The larger values for standard deviation in all of the Updated measurements indicate a shift in the distribution of the pellets within the overall range for that parameter.

**Table 4: Statistical Properties of Tray 1 Pellets, Legacy and Updated Values**

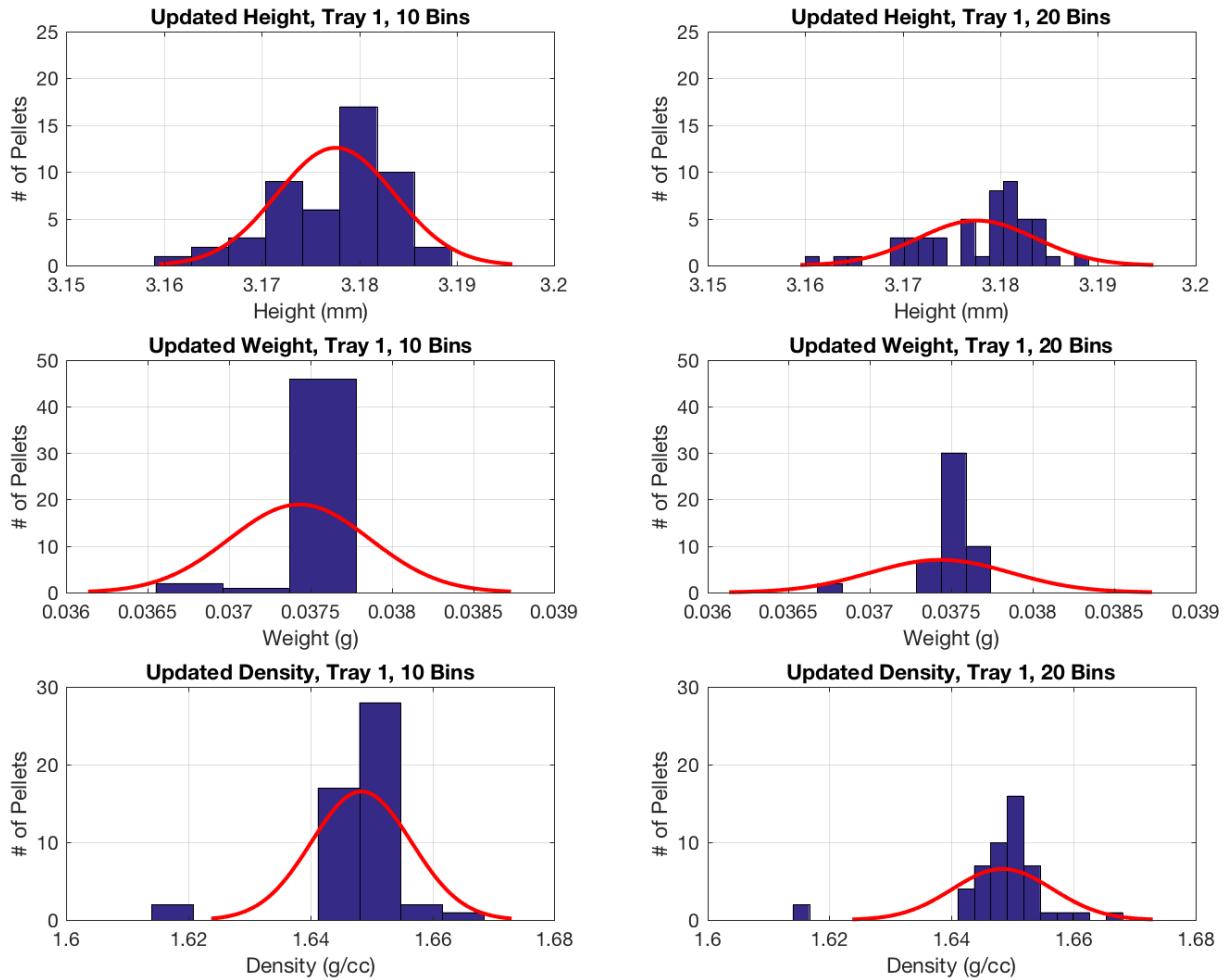
Parameter	Outer Diameter (mm)		Height (mm)		Weight (g)		Density (g/cc)	
Data Case	Legacy	Updated	Legacy	Updated	Legacy	Updated	Legacy	Updated
<b>Mean</b>	3.020	3.019	3.175	3.178	0.0375	0.0374	1.65	1.65
<b>Standard Deviation</b>	0	0.00074	0.00397	0.00603	0.000141	0.000433	0.00645	0.00820
<b>Mode</b>	3.020	3.019	3.175	3.181	0.0375	0.0375	1.65	1.65
<b>Median</b>	3.020	3.019	3.175	3.180	0.0375	0.0375	1.65	1.65
<b>Minimum</b>	3.020	3.017	3.162	3.160	0.0371	0.0347	1.63	1.62
<b>Maximum</b>	3.020	3.020	3.184	3.189	0.0378	0.0377	1.67	1.67

**Table 5: Statistical Properties of All Pellets, Legacy and Updated Values**

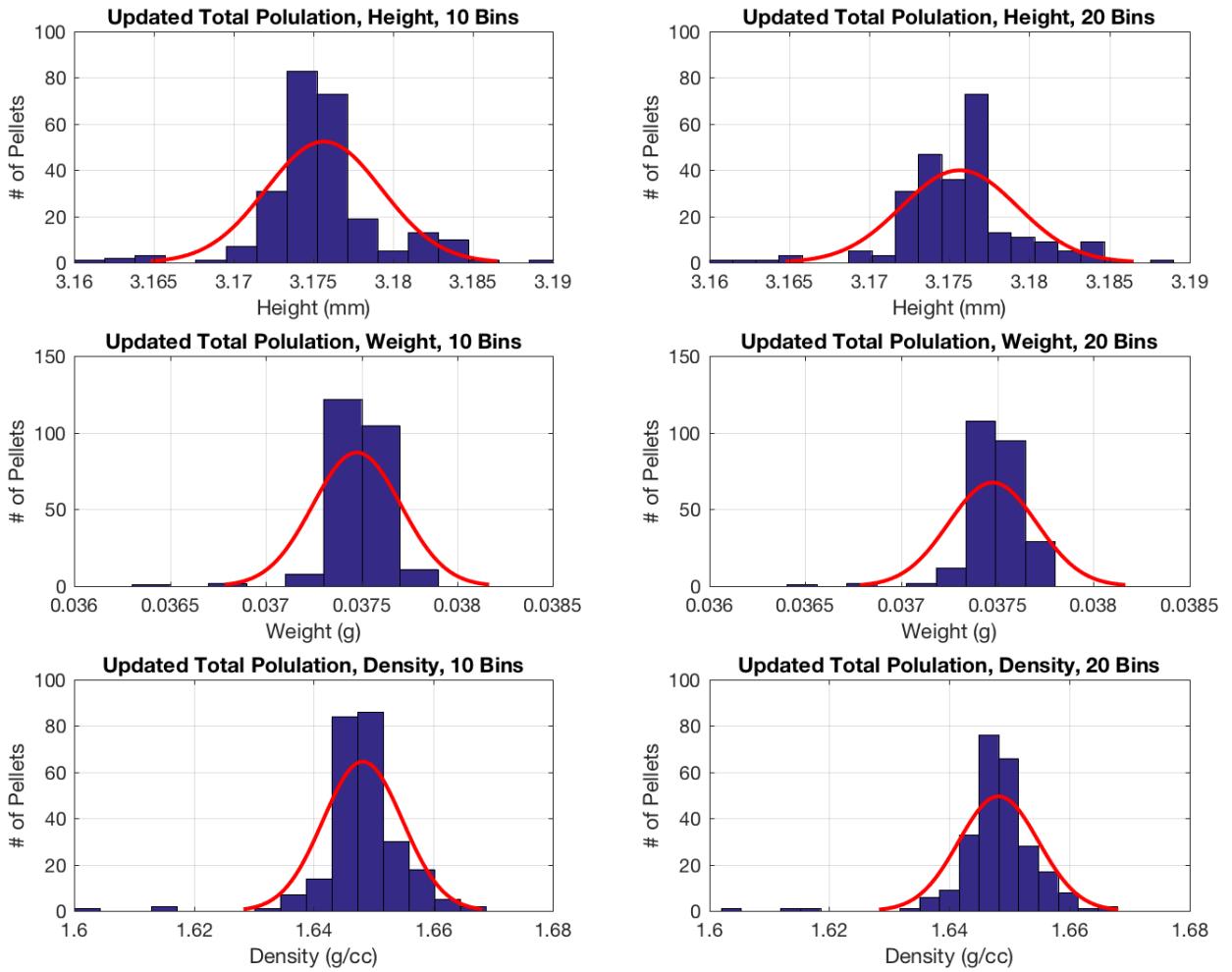
Parameter	Outer Diameter (mm)		Height (mm)		Weight (g)		Density (g/cc)	
Data Case	Legacy	Updated	Legacy	Updated	Legacy	Updated	Legacy	Updated
<b>Mean</b>	3.020	3.020	3.175	3.176	0.0375	0.0375	1.65	1.65
<b>Standard Deviation</b>	0	0.000615	0.00250	0.00362	0.000140	0.000230	0.00622	0.00664
<b>Mode</b>	3.020	3.020	3.174	3.174	0.0375	0.0375	1.65	1.65
<b>Median</b>	3.020	3.020	3.175	3.175	0.0375	0.0375	1.65	1.65
<b>Minimum</b>	3.020	3.017	3.162	3.160	0.0364	0.0347	1.60	1.60
<b>Maximum</b>	3.020	3.020	3.184	3.189	0.0378	0.0378	1.67	1.67

As with the Legacy datasets, histograms were plotted for the height, weight, and density of the Updated Tray 1 and Updated Total Population values, and the chi-squared goodness of fit test applied to possibly identify any distribution patterns for the new numbers. The Updated Tray 1 histograms, both default (10) bin and 2x default (20) bin,

are presented in **Figure 16**. As with the numerical evaluation for the Updated total population, the Updated histograms included in **Figure 17** represent 250 total number of pellets. An interesting feature of the Updated W histogram is the coalescence of the values to the center of the value range. Unsurprisingly, the Updated chi-squared testing results mimic the Legacy outcomes, with the null hypothesis that the data fits a normal distribution rejected for all cases of data except the Updated W values. For that case, however, the  $p$  value for the Updated W test cannot be calculated and is considered NaN by MATLAB for the same reason that the Legacy OD case could not be calculated. The values denoted simply as “0” in **Table 6** are calculable, but are so small (on the order of  $1*10^{-10}$  or smaller) they are considered to have a zero value. Table 6 collects and compares all of the Updated and Legacy distribution testing results. Additional histograms and tabulated testing values by parameter for the Updated data are included in the Appendix.



**Figure 16:** Updated 10 and 20 bin histograms for Tray 1.



**Figure 17:** Updated 10 and 20 bin histograms for Total Population.

**Table 6: Legacy and Updated Chi-Squared Goodness-of-Fit Testing Results**

Parameter		OD		H		W		D	
Test Case		Tray 1	Total Pop.	Tray 1	Total Pop.	Tray 1	Total Pop.	Tray 1	Total Pop.
<b>Legacy</b>	<b>Accept/Reject Null Hypothesis</b>	0	0	1	1	0	1	1	1
	<b>P Value</b>	NaN	NaN	0.00008	0.001	0.05	0.0007	0.0002	0.001
<b>Updated</b>	<b>Accept/Reject Null Hypothesis</b>	0	1	1	1	0	0	1	1
	<b>P Value</b>	NaN	0	0.00008	0	0.05	NaN	0.0002	0

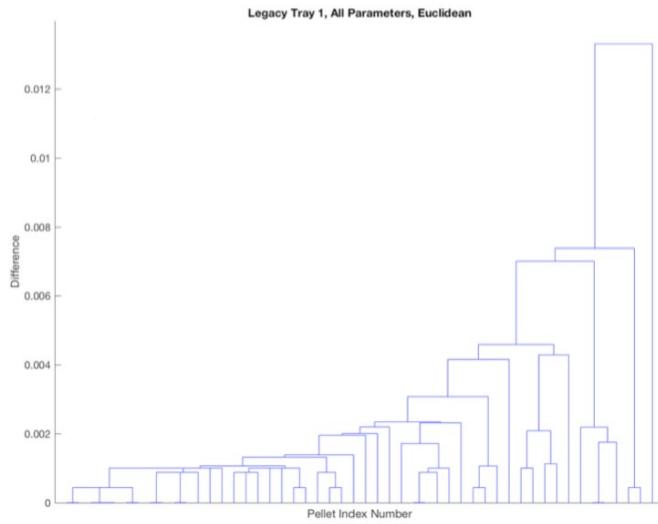
## *Machine Sorting and Clustering*

Having completed the statistical evaluation for the pellets to build an understanding of the characteristics of both the Legacy and Updated populations, the next step is applying SHM methods to sort and analyze the data. This process starts by building branch-and-leaf plots, or dendograms, for the given data. The default dendrogram command in MATLAB creates binary pairs of pellets based on the Euclidean distance between the pellet dimensions,  $E$ , represented per **Equation 1** below where subscripts  $n$  and  $m$  represent the two pellets being compared. Each binary pair is then grouped with the next closest (in value) pair, continuing this pairing process until no remaining pairs can be created [11]. **Figure 18** illustrates a completed dendrogram for the Legacy pellets in Tray 1. The pellet index numbers are plotted along the bottom axis, with the value difference between the pairs along the vertical axis. Because the pellets are paired based on the measurement data and the pairs exhibiting the smallest Euclidian distance are plotted toward the left of the dendrogram, the pellet index axis does not move in ascending order. This “scrambling” of the pellet index values is demonstrated in **Figure 19**, which is a close-in view of the origin area of Figure 18. For the purpose of this investigation the identification of which pellets are paired is not as important as the overall shape of the dendrogram; therefore, the individual pellet index values have been removed from view to simplify the dendrogram displays. The values along the vertical axis are unitless, representing the absolute value of the Euclidian distance between the binary pellet pairs at the lowest level and the grouped pairs for ascending levels.

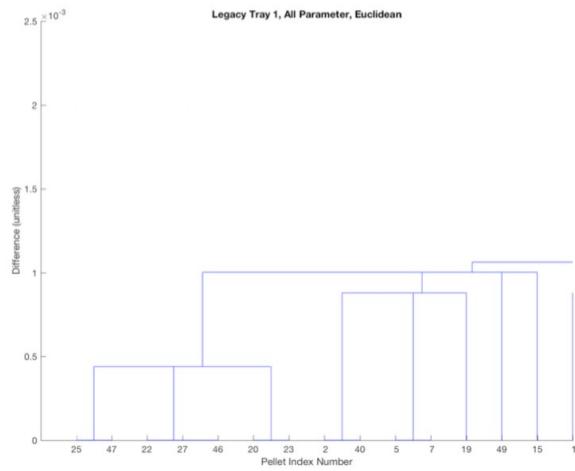
$$E_{mn} = \sqrt{(OD_n - OD_m)^2 + (H_n - H_m)^2 + (W_n - W_m)^2 + (D_n - D_m)^2} \quad (\text{EQN 1})$$

The Euclidean analysis for this data evaluation is performed on non-normalized data such that the contribution to the equation from the difference in weights between pellets is dominated by the parameters with larger orders of magnitude, height and density. While one approach to achieving a more equalized distance value would be statistically standardizing all parameters then evaluating the distances, a more direct approach was selected to retain the highest possible degree of data integrity: using the Cityblock distance. Often called the Manhattan distance, the Cityblock distance, as referenced in **Equation 2**, calculates the distances between pellet parameter directly. In this way, each parameter contributes in equal measure to the distance between the pellets; for this reason, Cityblock is often recommended for applications wherein dimensions with disparate magnitude are to be evaluated [10].

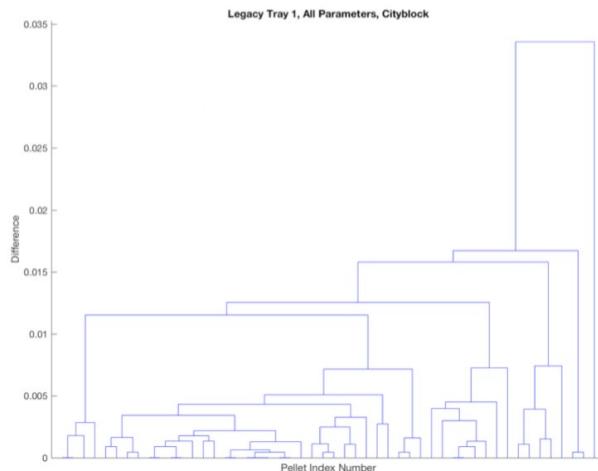
$$CB_{mn} = (OD_n - OD_m) + (H_n - H_m) + (W_n - W_m) + (D_n - D_m) \quad (\text{EQN 2})$$



**Figure 18:** Legacy Tray 1 dendrogram configured based on Euclidian distances.



**Figure 19:** Close view of Legacy Tray 1 dendrogram illustrating pellet index number rearrangement based on dendrogram pairing algorithm.



**Figure 20:** Legacy Tray 1 dendrogram configured based on Cityblock distances.

Comparing the dendrogram in **Figure 20** of Legacy Tray 1 data computed using the Cityblock equation yields a more uniform difference between the grouped pairs compared to the same information presented as Euclidian-based dendrogram of Figure 18. The difference in distance equation use is even more apparent in the Euclidian and Cityblock dendrograms for the Legacy total pellet population plots as illustrated in **Figure 21** and **Figure 22** respectively. The range in the vertical axis “Difference” numbers are of similar magnitude for the two images, but the increased contribution of the weight parameter for the Cityblock distance slightly raises the actual value; also note how the “branches” of the Euclidian result have very little vertical differentiation, whereas the Cityblock results have greater vertical variability. Additional dendrograms for other Legacy Trays and parameters not presented here are collected in the Appendix.

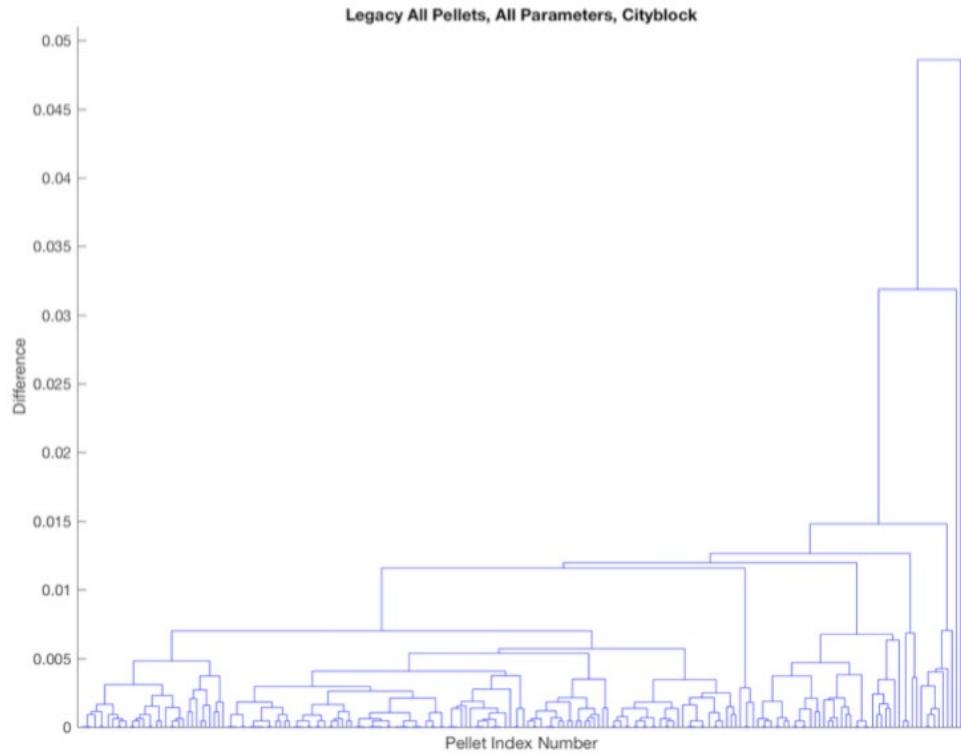
Beyond creating a more aesthetically pleasing graphic, computing the distance between pellets and pellets pair and groups using the Cityblock method provides a quantifiable advantage over the Euclidian technique. The cophenetic correlation coefficient,  $c$ , found using **Equation 3** is a measure of how well the dendrogram building equation pairs the data relative to the “closeness” calculated by the chosen distance formula (in this case, Euclidian or Cityblock) [11]. In the  $c$  equation,  $Y_{mn}$  represents the distance between two pellets,  $Y$  is the average value of all  $Y_{mn}$  values,  $Z_{mn}$  the vertical distance of the dendrogram branch linking the two pellets, and  $Z$  is the average vertical distance for all branches in the dendrogram. Essentially, a cophenetic correlation coefficient of “1” would indicate that the pairing and grouping of the data in the dendrogram exactly matches the progressively increasing computed distances between the data points; the closer to 1 the cophenetic correlation coefficient, the better the dendrogram represents the data set. For the pellet data, the cophenetic correlation coefficient was found for both the Euclidian and Cityblock analysis cases. The results, collected for Legacy Tray 1 and Legacy total population in **Table 7**, show an increased cophenetic correlation coefficient for both Legacy Tray 1 and Legacy total population when the Cityblock equation is used to calculate the paired and grouped distances.

$$c = \frac{\sum(Y_{mn} - Y)(Z_{mn} - Z)}{\sqrt{\sum(Y_{mn} - Y)^2(Z_{mn} - Z)^2}} \quad (\text{EQN 3})$$

$$i_{mn} = \frac{(Z_{mn} - Z_{mn-1})}{\sigma Z_{mn}} + \frac{(Z_{mn} - Z_{mn-2})}{\sigma Z_{mn}} \quad (\text{EQN 4})$$



**Figure 21:** Legacy total population dendrogram configured based on Euclidian distances.



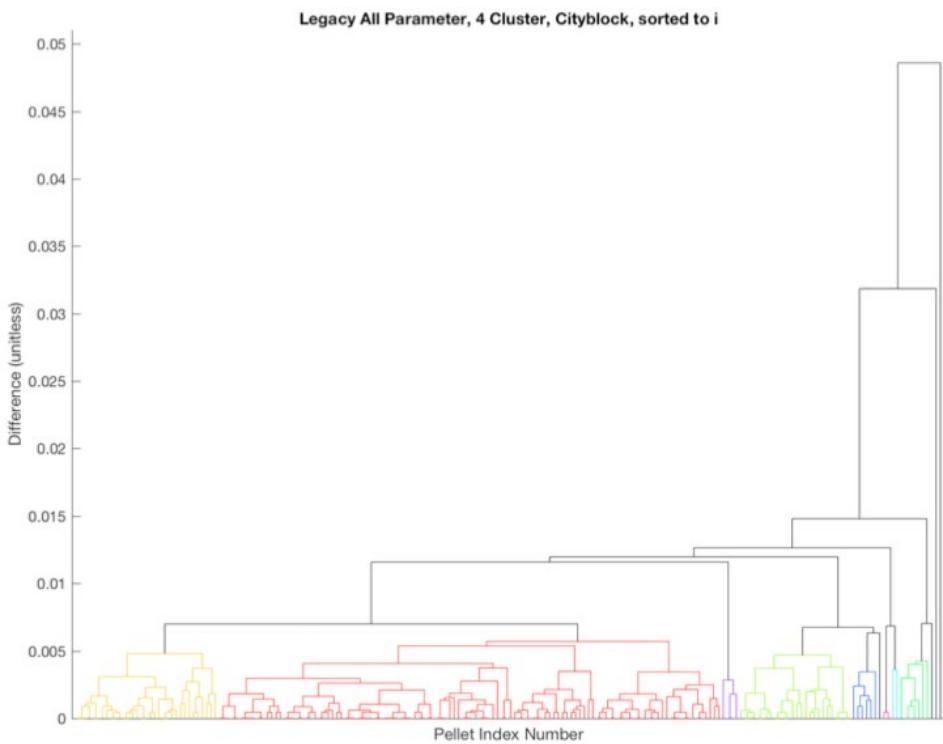
**Figure 22:** Legacy total population dendrogram configured based on Cityblock distances.

**Table 7: Legacy Cophenetic and Inconsistency Coefficients**

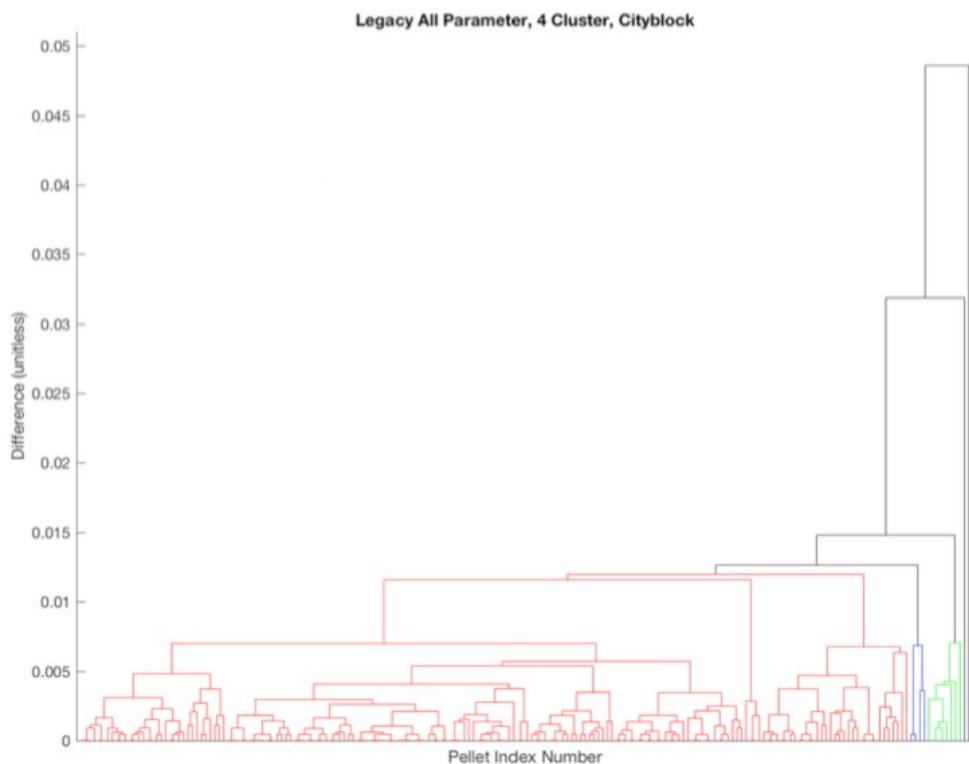
Calculation Method	Euclidian		Cityblock	
<b>Legacy Values</b>	Tray 1	Total Population	Tray 1	Total Population
Cophenetic Coeff. $c$	0.7634	0.7660	0.8800	0.8731
Max. Inconsis. Coeff. $i$	1.155	1.155	1.155	1.155

In addition to the cophenetic correlation coefficient, a value called the inconsistency coefficient,  $i_{mn}$ , is calculated (via [Equation 4](#)) for the Euclidian and Cityblock results. To find this coefficient, the vertical difference value for each branch of the dendrogram,  $Z_{mn}$ , is compared to the vertical difference for the branches of groups one and two levels lower in the hierarchy,  $Z_{mn-1}$  and  $Z_{mn-2}$  respectively <sup>[11]</sup>. Those values are divided by the standard deviation value for all vertical values in the dendrogram,  $\sigma_{Z_{mn}}$ . The maximum inconsistency value represents the maximum disparity between two sets of vertical differences on the dendrogram. A higher maximum value for inconsistency coefficients represent stronger natural divisions in the given data set, although what constitutes a “high” inconsistency value is dependent on the data. Fortunately, for the evaluation of the pellets the maximum inconsistency coefficient value is the same whether the data is analyzed using the either the Euclidian or the Cityblock equation, as demonstrated in Table 7. Tabulated results for the remaining Legacy Trays can be found in the Appendix. Because organizing the pellet data for both Legacy Tray 1 and the Legacy total population using the Cityblock method returns a higher cophenetic correlation coefficient with no change in the inconsistency coefficient, the Cityblock pairing and grouping results are used as the numerical model for the next step in the SHM process: clustering.

Similar to the multiple methods that can be used to build dendograms, a given data set can be clustered based on different selected parameters. Common techniques for clustering data include one method based around the inconsistency coefficient to sort along natural divides in the dataset, and a second method that designates a maximum number of clusters among which each data point must be sorted. [Figure 23](#) illustrates the Legacy total population data sorted based on the former method; using an average of the ten highest inconsistency coefficients found when the values are grouped based on Cityblock distances, for which each color represents a defined cluster. When a maximum number of clusters is selected as the basis for sorting, the machine code must decide how the clusters are arranged and where the cutoff values for each group are. The Legacy total population data sorted into a maximum of four clusters is presented in [Figure 24](#). The number of maximum clusters was selected as four because the pellets are stored in four trays.

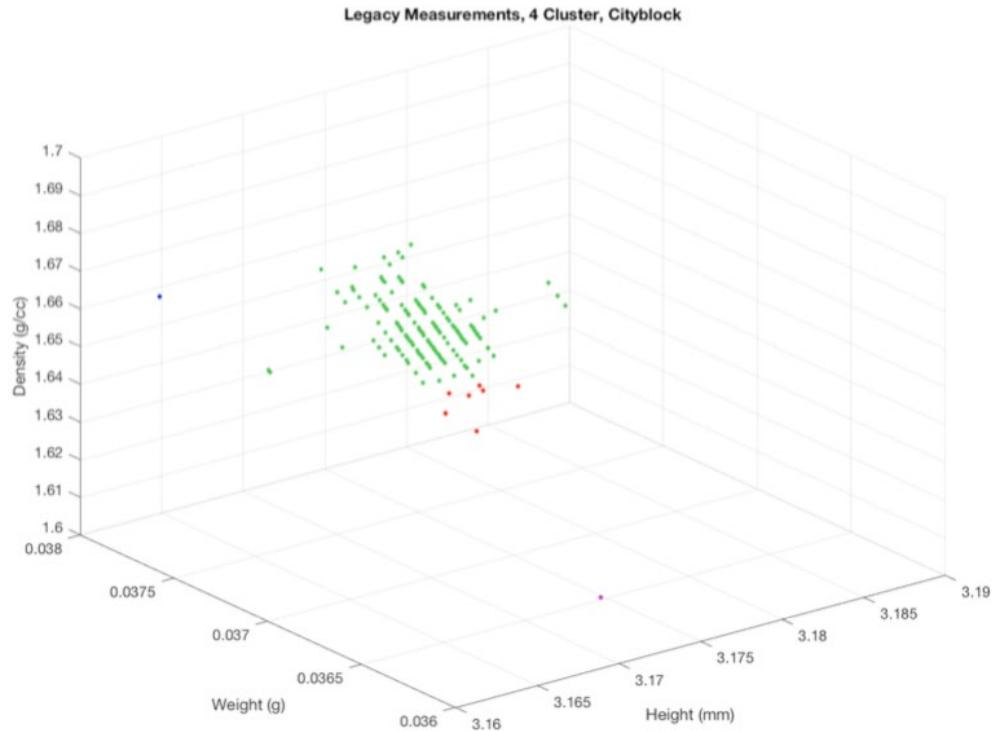


**Figure 23:** Legacy total population sorted according to the average of the then highest inconsistency coefficient values.



**Figure 24:** Legacy total population data sorted into four clusters with size determined by MATLAB.

**Figure 25** represents each Legacy total population point as sorted into one of four clusters by the MATLAB program, with cluster indicated by color. The pellets identified earlier as anomalies (1-28, 1-29, 1-30, 1-31, 1-36, 1-44, 1-45, 1-48, and 2-36) have been sorted out of the main population, in addition to pellet 3-4 which was previously unidentified for above-typical height. **Table 8** identifies how many pellets are in each cluster, and from which tray the clusters are formed. Although most of the work up to this point has included analysis for Legacy Tray 1 in addition to the Legacy total population, Legacy Tray 1 is not considered independently during clustering, because the significance of pellet clustering is identifying outliers from the total population, not within each individual tray. Comparing the results of this Legacy total population sorting exercise to the sorted results when the Updated Tray 1 data is added is the crux of this investigation, and the crucial factor in proving the appended code is viable as a SHM solution for identifying the usability of pellets after long-term storage.

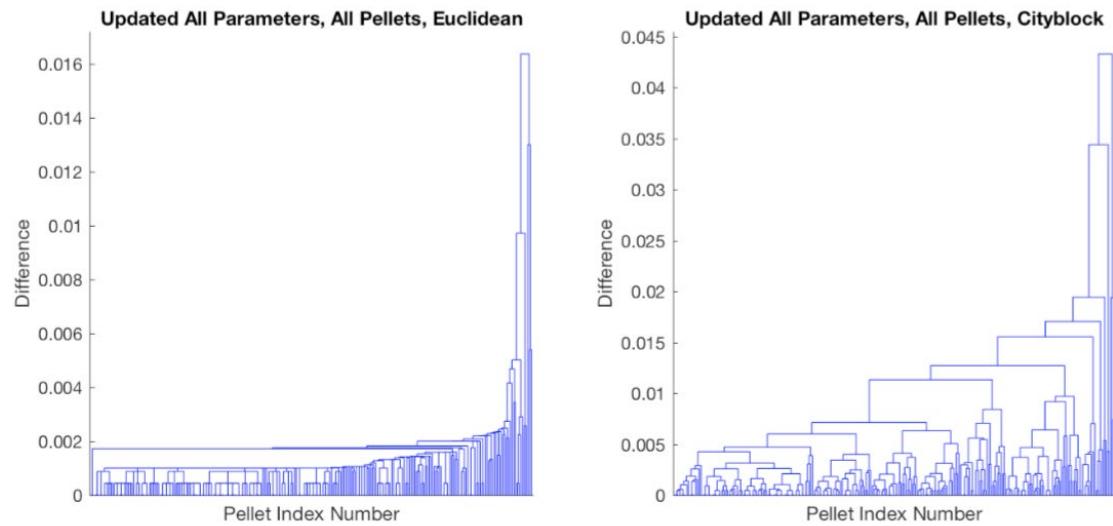


**Figure 25:** Legacy total population data points sorted into four clusters.

**Table 8: Four Cluster Breakdown for Legacy Total Population**

Cluster	Legacy Tray 1	Legacy Tray 2	Legacy Tray 3	Legacy Tray 4
Blue	1	0	0	0
Green	42	49	49	50
Red	7	0	1	0
Purple	0	1	0	0

With the analysis complete for the Legacy data, the Updated Tray 1 values are added to the Legacy total population. As was done for the statistical evaluation, these Updated values are simply added to the end of the Legacy dataset instead of replacing the Legacy Tray 1 values so that the Updated information can be tracked alongside the original values. The same calculations were made to verify the Cityblock distance equations remained the most suitable for data pairing and grouping; it is clear from the comparison of the Euclidian and Cityblock dendograms for the Updated total population in **Figure 26** and the tabulated results in **Table 9** that it does. Additional dendograms and tabulated values for cophenetic and inconsistency coefficients are collected in the Appendix.



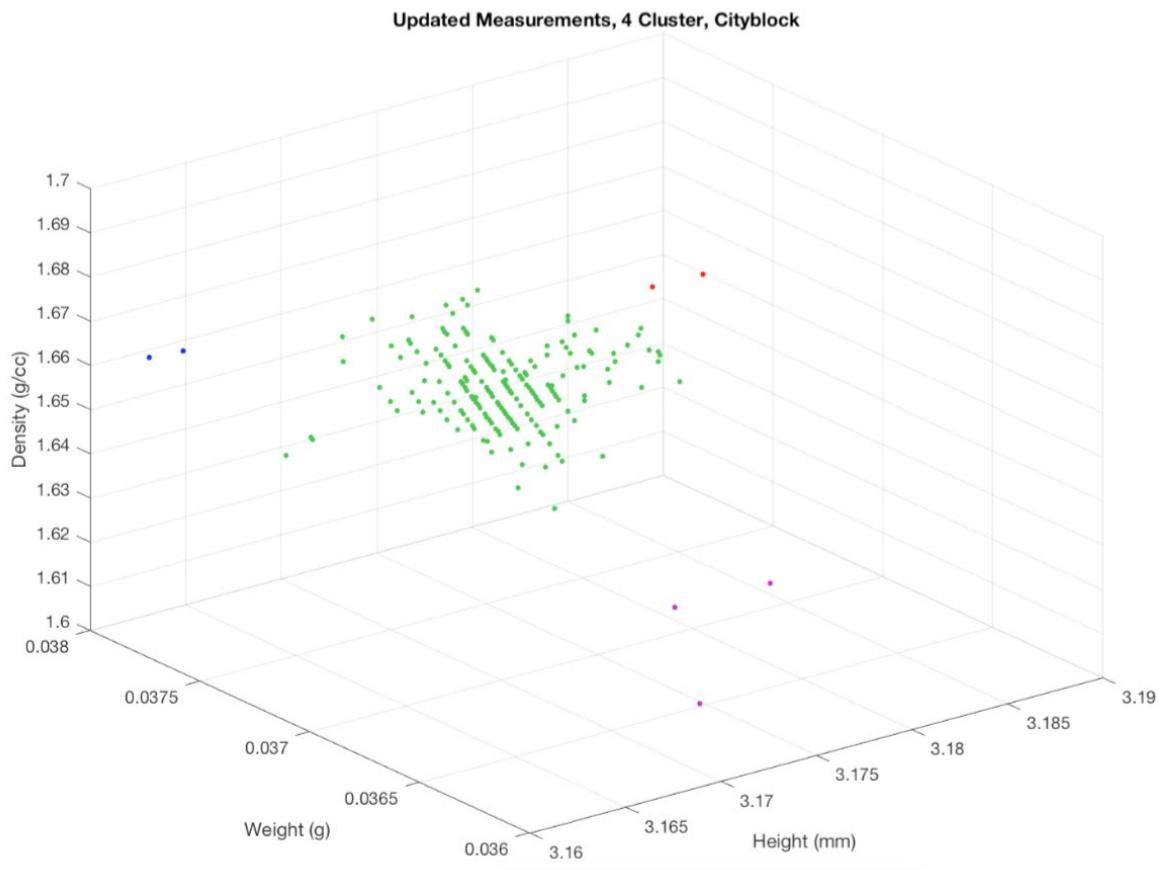
**Figure 26:** Euclidian and Cityblock dendograms for Updated total population.

**Table 9: Updated Cophenetic and Inconsistency Coefficients**

Calculation Method	Euclidian	Cityblock
	Updated Total Population	Updated Total Population
Cophenetic Coeff. $c$	0.8254	0.8786
Max. Inconsis. Coeff. $i$	1.155	1.155

Again the total population is clustered into four groups, illustrated by **Figure 27**, but with the Updated Tray 1 measurements included the results change slightly when compared to the Legacy total population sorting. The new anomalies recognized during the initial statistical evaluation of the Updated Tray 1 information are now sorted into the four groups, with two pellets from Updated Tray 1 forming their own cluster, three other pellets joining the two other outlier groups formed by two of the Legacy pellets, and the seven pellets from Legacy Tray 1 originally sorted into their own cluster have now joined the largest cluster. The distribution of the Legacy and Updated pellets, by

tray, among the four clusters is collected in **Table 10**. From the tabulated data combined with the figure, it is evident that the blue cluster represents pellet 1-36, which was the lowest recorded height for the Legacy Tray 1 and again for the Updated Tray 1 values. The two Updated Tray 1 underweight pellets 1-40 and 1-45 have joined the Legacy Tray 2 pellet 2-36 in the purple group, the pellets found to have larger heights in Updated Tray 1 (1-9 and 1-14) are segregated in the red cluster, and the slightly tall pellet from Legacy Tray 3 has been returned to the green general populous cluster.

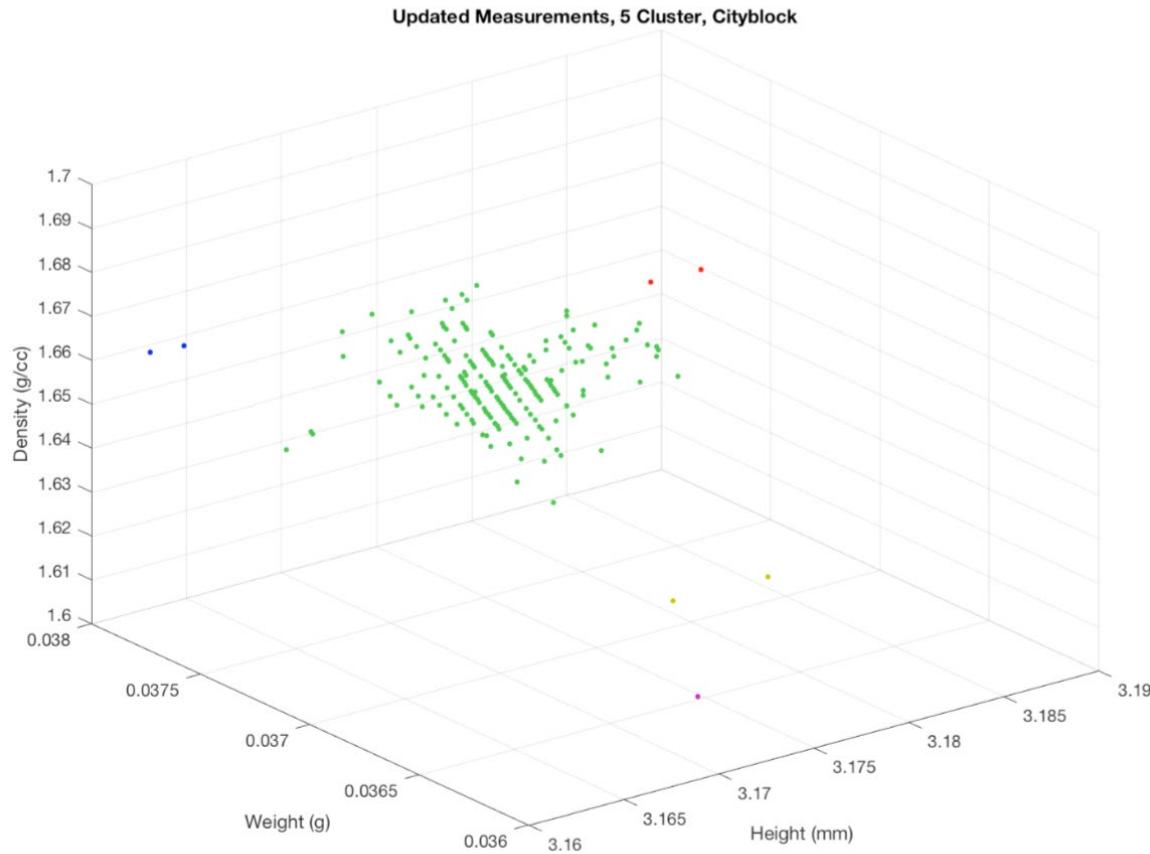


**Figure 27:** Updated total population sorted into four clusters.

**Table 10: Four Cluster Breakdown for Updated Total Population**

Cluster	Legacy Tray 1	Legacy Tray 2	Legacy Tray 3	Legacy Tray 4	Updated Tray 1
Blue	1	0	0	0	1
Green	49	49	50	50	45
Red	0	0	0	0	2
Purple	0	1	0	0	2

The clustering command was repeated with a maximum cluster value of five to determine if allowing additional groups would divide the most heavily populated cluster, but, as **Figure 28** and **Table 11** show, the only result was to separate 1-40 and 1-45 from Updated Tray 1 from 2-36 in Legacy Tray 2. While it is probable that increasing the maximum number of allowable clusters would identify more groups populated primarily with Legacy and Updated Tray 1 pellets, both the four and five cluster results indicate that the majority of the Updated Tray 1 pellets have retained geometric dimensions within the original process variation envelope.



**Figure 28:** Updated total population sorted into five clusters.

**Table 11: Five Cluster Breakdown for Updated Total Population**

Cluster	Legacy Tray 1	Legacy Tray 2	Legacy Tray 3	Legacy Tray 4	Updated Tray 1
Blue	1	0	0	0	1
Green	49	49	50	50	45
Red	0	0	0	0	2
Yellow	0	0	0	0	2
Purple	0	1	0	0	0

## CONCLUSIONS

Knowing that the Legacy Tray 1 pellets started with more variation within each parameter, the results of this SHM experiment are encouraging. Of the five pellets sorted out of the green cluster, one was also identified as an outlier in the Legacy data and the other four were clearly recognized as out-of-normal by the sorting algorithm. Because the remaining three trays were manufactured with much less variation, this investigation provided significant evidence to support the use of those pellets, even after their prolonged storage. This report also serves to suggest that the production PETN pellets well in advance of demand may be a viable option for coordinating manufacturing schedules and budgets.

If research into pellet longevity is continued in the future, improvements are recommended mainly regarding the methods used to collect the pellet dimensions. The pellets are small and delicate in nature, and using contact measurement methods such as micrometers and indicator-over-base are likely to harm or entirely destroy the pellets; it is possible that the four pellets that exhibited noticeable changes from Legacy to Updated Tray 1 were damaged during the re-measuring process. Additional and more informative correlations between pellet and storage conditions may be determined if an environmental monitoring system was added to the long-term storage areas.

## REFERENCES

- [1] US Climate Data. (2006-2018). Retrieved on 15 September 2018 from [www.usclimatedata.com/climate/new-mexico/united-states/3201](http://www.usclimatedata.com/climate/new-mexico/united-states/3201)
- [2] Burnham, A., Qiu, S., Pitchimani, R., & Weeks, B. (2009). Comparison of kinetic and thermodynamic parameters of single crystal pentaerythritol tetranitrate using atomic force microscopy and thermogravimetric analysis: Implications on coarsening mechanisms. *Journal of Applied Physics*, 105(10). DOI: 10.1063/1.3129504
- [3] Edmonds, E., Hazelwood, A., Lilly, T., & Mansell, J. (2007). Development of in-situ surface area analysis for detonators. *Powder Technology*, 174(1), 42-45. DOI: 10.1016/j.powtec.2006.10.019
- [4] Maiti, A., Han, Y., Zaka, F., & Gee, R. (2015). In-situ Monitoring of Flow-Permeable Surface Area of High Explosive Powder using Small Sample Masses. *Propellants, Explosives, Pyrotechnics*, 40(3), 419-425. DOI: 10.1002/prep.201400289

- [5] Hikal, W., Bhattacharia, S., Peterson, G., & Weeks, B. (2012). Controlling the coarsening stability of pentaerythritol tetranitrate (PETN) single crystals by the use of water. *Thermochimica Acta*, 536, 63-67. DOI: 10.1016/j.tca.2012.02.026
- [6] Foltz, M. (2009). Aging of Pentaerythritol Tetranitrate (PETN). DOI: 10.2172/966904
- [7] Hsu, P. (2017). Thermal safety characterization on PETN, PBX-9407, LX-10-2, LX-17-1 and detonator in the LLNL's P-ODTX system. DOI: 10.2172/1396199
- [8] Maiti, A., Olson, T., Han, T., & Gee, R. (2017). Long-term Coarsening and Function-time Evolution of an Initiator Powder. *Propellants, Explosives, Pyrotechnics*, 42(12), 1352-1357. DOI: 10.1002/prep.201700186
- [9] Gibbs, T., Popolato, A., & Los Alamos Scientific Laboratory. (1980). *LASL Explosive Property Data*. Berkeley, Los Angeles, Calif.: University of California Press.
- [10] Taylor, K. (2017). *Machine Learning with MATLAB: Unsupervised [sic] Learning and Clustering*. Scotts Valley, Calif.: CreateSpace Publishing.
- [11] MATLAB (and Statistics and Machine Learning Toolbox) Release 2018a, The MathWorks, Inc., Natick, Massachusetts, United States.

## Table of Contents

SE 296 Project .....	1
Legacy Data Import .....	1
Legacy Data Plotting .....	2
Legacy Data 3D Scatter Plots .....	3
Legacy Data Statistics .....	6
Legacy Data Histograms .....	11
Legacy Data Testing .....	22
Legacy Data Machine Sorting and Dendograms .....	24
Legacy Data Cophenetic Distances and Inconsistency Coefficients .....	40
Legacy Data Machine Clustering .....	42
Updated Data Import .....	49
Updated Data Plotting .....	49
Updated Data 3D Scatter Plot .....	51
Updated Data Statistics .....	53
Updated Data Histograms .....	56
Updated Data Testing .....	68
Updated Data Machine Sorting and Dendograms .....	69
Updated Data Cophenetic Distances and Inconsistency Coefficients .....	81
Updated Data Clustering .....	84

## SE 296 Project

Katelyn Yeamans UCSD Fall 2018

```
clc;
close all;
clear all;
```

## Legacy Data Import

Load the initial measurement data for: Legacy Diameter

```
od = xlsread('legacy_od.xlsx');
odl = [od(:,1); od(:,2); od(:,3); od(:,4)]; % arrange all data in one
% column
% Legacy Height
h = xlsread('legacy_height.xlsx');
hl = [h(:,1); h(:,2); h(:,3); h(:,4)];
% Legacy Weight
w = xlsread('legacy_weight.xlsx');
wl = [w(:,1); w(:,2); w(:,3); w(:,4)];
% Legacy Density
d = xlsread('legacy_density.xlsx');
dl = [d(:,1); d(:,2); d(:,3); d(:,4)];
% Legacy All Data (ODxHxWxD for 200 pellets)
al = xlsread('legacy_all.xlsx');
% Tray Index Assignment for Clustering
tray(1:50) = {'Tray 1'};
tray(51:100) = {'Tray 2'};
```

---

```

tray(101:150) = {'Tray 3'};
tray(151:200) = {'Tray 4'};

Legacy Data Plotting

p = 1:1:50; % index for pellet position

% Plot Legacy Diameter
figure('name','Legacy Measurement Data')
ax1 = subplot(2,2,1);
scatter(p,od(:,1),'filled')
hold on
scatter(p,od(:,2),'filled')
scatter(p,od(:,3),'filled')
scatter(p,od(:,4),'filled')
xlim([1 50])
ylim([2.9 3.1])
legend(ax1,'Tray 1','Tray 2','Tray 3','Tray
4','Location','southoutside','Orientation','horizontal');
title('Legacy Diameter')
xlabel('Pellet Index Number')
ylabel('Pellet Diameter (mm)')

grid on

% Plot Legacy Height
subplot(2,2,2)
scatter(p,h(:,1),'filled')
hold on
scatter(p,h(:,2),'filled')
scatter(p,h(:,3),'filled')
scatter(p,h(:,4),'filled')
xlim([1 50])
ylim([3.16 3.19])
%legend('Tray 1','Tray 2','Tray 3','Tray
4','location','northeastoutside')
title('Legacy Height')
xlabel('Pellet Index Number')
ylabel('Pellet Height (mm)')
grid on

% Plot Legacy Weight
subplot(2,2,3)
scatter(p,w(:,1),'filled')
hold on
scatter(p,w(:,2),'filled')
scatter(p,w(:,3),'filled')
scatter(p,w(:,4),'filled')
xlim([1 50])
ylim([0.0360 0.0380])
%legend('Tray 1','Tray 2','Tray 3','Tray
4','location','northeastoutside')
title('Legacy Weight')

```

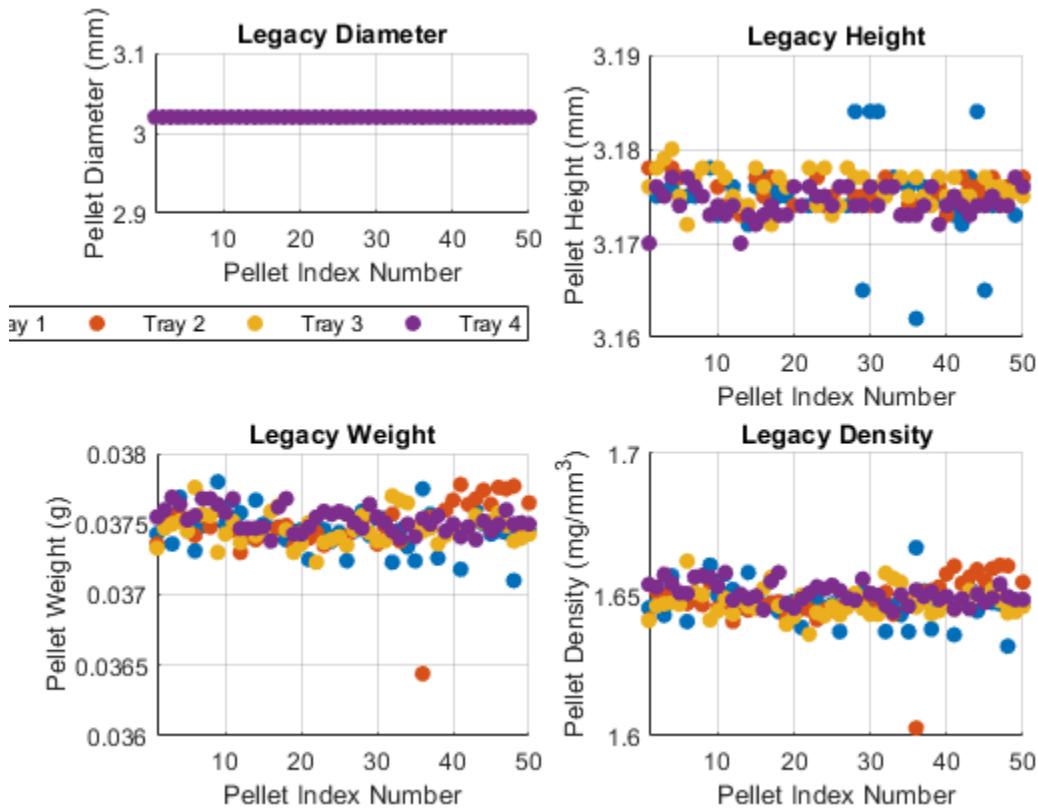
---

```

xlabel('Pellet Index Number')
ylabel('Pellet Weight (g)')
grid on

% Plot Legacy Density
subplot(2,2,4)
scatter(p,d(:,1), 'filled')
hold on
scatter(p,d(:,2), 'filled')
scatter(p,d(:,3), 'filled')
scatter(p,d(:,4), 'filled')
xlim([1 50])
ylim([1.6 1.7])
%legend('Tray 1','Tray 2','Tray 3','Tray 4','location','northeastoutside')
title('Legacy Density')
xlabel('Pellet Index Number')
ylabel('Pellet Density (mg/mm^{3})')
grid on

```



## Legacy Data 3D Scatter Plots

```

for i = 1:4
    x(:,i) = h(:,i);
    y(:,i) = w(:,i);
    z(:,i) = d(:,i);

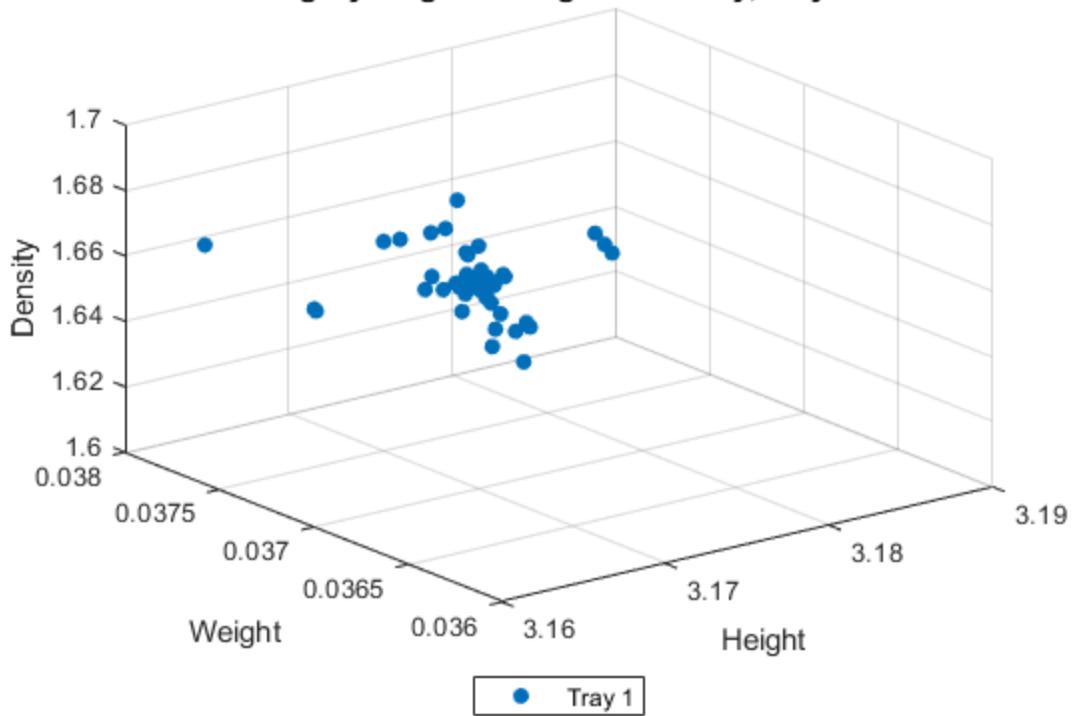
```

---

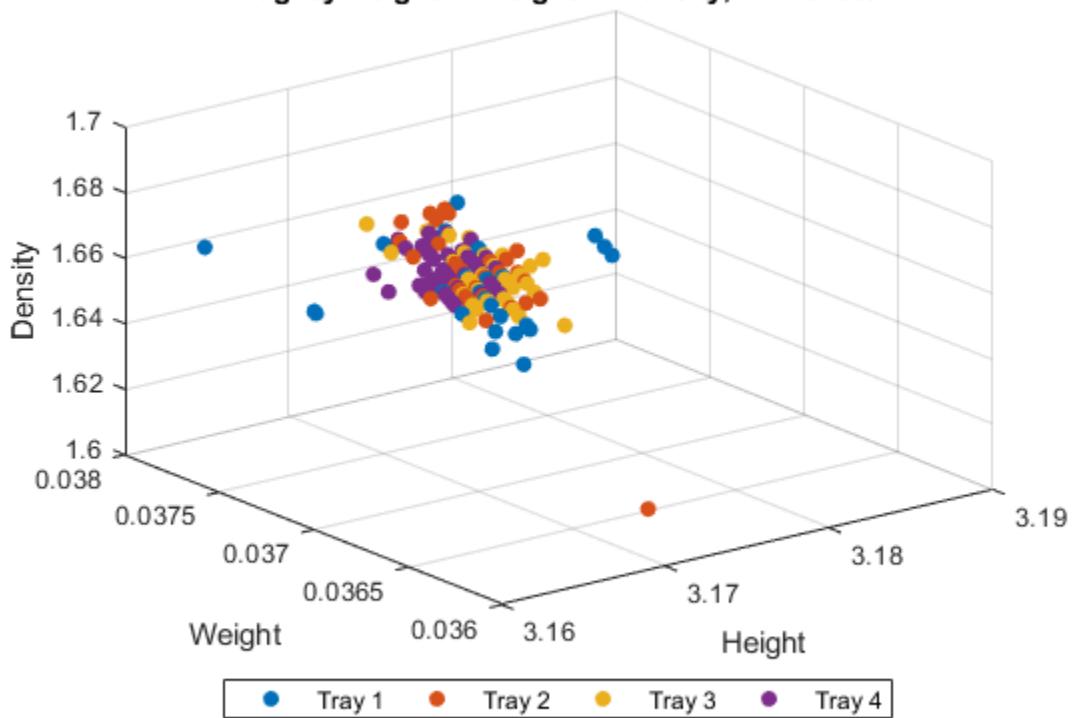
```
end
figure('name','Legacy Height v. Weight v. Density by Tray')
scatter3(x(:,1),y(:,1),z(:,1),'filled')
title('Legacy Height v. Weight v. Density, Tray 1')
xlabel('Height')
ylabel('Weight')
zlabel('Density')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
legend('Tray 1','location','southoutside','orientation','horizontal')

figure('name','Legacy Height v. Weight v. Density, All Pelets')
scatter3(x(:,1),y(:,1),z(:,1),'filled')
hold on
scatter3(x(:,2),y(:,2),z(:,2),'filled')
scatter3(x(:,3),y(:,3),z(:,3),'filled')
scatter3(x(:,4),y(:,4),z(:,4),'filled')
title('Legacy Height v. Weight v. Density, All Pellets')
xlabel('Height')
ylabel('Weight')
zlabel('Density')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
legend('Tray 1','Tray 2','Tray 3','Tray
4','location','southoutside','orientation','horizontal')
cmap = colormap;
```

**Legacy Height v. Weight v. Density, Tray 1**



**Legacy Height v. Weight v. Density, All Pellets**



---

# Legacy Data Statistics

For Legacy Diameter

```
odmean = mean(od);
odstd = std(od);
odmode = mode(od);
odmedian = median(od);
odmin = min(od);
odmax = max(od);

% For Legacy Height
hmean = mean(h);
hstd = std(h);
hmode = mode(h);
hmedian = median(h);
hmin = min(h);
hmax = max(h);

% For Legacy Weight
wmean = mean(w);
wstd = std(w);
wmode = mode(w);
wmedian = median(w);
wmin = min(w);
wmax = max(w);

% For Legacy Density
dmean = mean(d);
dstd = std(d);
dmode = mode(d);
dmedian = median(d);
dmin = min(d);
dmax = max(d);

% For Legacy Total Populations
odlmean = mean(odl);
hlmean = mean(hl);
wlmean = mean(wl);
dlmean = mean(dl);
odlstd = std(odl);
hlstd = std(hl);
wlstd = std(wl);
dlstd = std(dl);
odlmode = mode(odl);
hlmode = mode(hl);
wlmode = mode(wl);
dlmode = mode(dl);
odlmedian = median(odl);
hlmedian = median(hl);
wlmedian = median(wl);
dlmedian = median(dl);
odlmin = min(odl);
```

---

```

hlmin = min(hl);
wlmin = min(wl);
dlmin = min(dl);
odlmax = max(odl);
hlmax = max(hl);
wlmax = max(wl);
dlmax = max(dl);

% Organize Legacy Statistical Data by Tray
tstattable1 = {[{'Mean'} odmean(1) hmean(1) wmean(1) dmean(1); {'STD'}
    odstd(1) hstd(1) wstd(1) dstd(1); {'Mode'} odmode(1) hmode(1) wmode(1)
    dmode(1); {'Median'} odmedian(1) hmedian(1) wmedian(1) dmedian(1);
    {'Min'} odmin(1) hmin(1) wmin(1) dmin(1); {'Max'} odmax(1) hmax(1)
    wmax(1) dmax(1)];
tstattable2 = {[{'Mean'} odmean(2) hmean(2) wmean(2) dmean(2); {'STD'}
    odstd(2) hstd(2) wstd(2) dstd(2); {'Mode'} odmode(2) hmode(2) wmode(2)
    dmode(2); {'Median'} odmedian(2) hmedian(2) wmedian(2) dmedian(2);
    {'Min'} odmin(2) hmin(2) wmin(2) dmin(2); {'Max'} odmax(2) hmax(2)
    wmax(2) dmax(2)];
tstattable3 = {[{'Mean'} odmean(3) hmean(3) wmean(3) dmean(3); {'STD'}
    odstd(3) hstd(3) wstd(3) dstd(3); {'Mode'} odmode(3) hmode(3) wmode(3)
    dmode(3); {'Median'} odmedian(3) hmedian(3) wmedian(3) dmedian(3);
    {'Min'} odmin(3) hmin(3) wmin(3) dmin(3); {'Max'} odmax(3) hmax(3)
    wmax(3) dmax(3)];
tstattable4 = {[{'Mean'} odmean(4) hmean(4) wmean(4) dmean(4); {'STD'}
    odstd(4) hstd(4) wstd(4) dstd(4); {'Mode'} odmode(4) hmode(4) wmode(4)
    dmode(4); {'Median'} odmedian(4) hmedian(4) wmedian(4) dmedian(4);
    {'Min'} odmin(4) hmin(4) wmin(4) dmin(4); {'Max'} odmax(4) hmax(4)
    wmax(4) dmax(4)];

% Display in tables
LegacyTray1Stats = cell2table(tstattable1,'VariableNames',
    {'Parameter','OD_mm','H_mm','W_g','D_g_per_cc'});
LegacyTray2Stats = cell2table(tstattable2,'VariableNames',
    {'Parameter','OD_mm','H_mm','W_g','D_g_per_cc'});
LegacyTray3Stats = cell2table(tstattable3,'VariableNames',
    {'Parameter','OD_mm','H_mm','W_g','D_g_per_cc'});
LegacyTray4Stats = cell2table(tstattable4,'VariableNames',
    {'Parameter','OD_mm','H_mm','W_g','D_g_per_cc'});

% Organize Legacy Data by Parameter
gstattable1 = [1 odmean(1) odstd(1) odmode(1) odmedian(1) odmin(1)
    odmax(1);2 odmean(2) odstd(2) odmode(2) odmedian(2) odmin(2)
    odmax(2);3 odmean(3) odstd(3) odmode(3) odmedian(3) odmin(3)
    odmax(3);4 odmean(4) odstd(4) odmode(4) odmedian(4) odmin(4)
    odmax(4)];
gstattable2 = [1 hmean(1) hstd(1) hmode(1) hmedian(1) hmin(1)
    hmax(1);2 hmean(2) hstd(2) hmode(2) hmedian(2) hmin(2) hmax(2);3
    hmean(3) hstd(3) hmode(3) hmedian(3) hmin(3) hmax(3);4 hmean(4)
    hstd(4) hmode(4) hmedian(4) hmin(4) hmax(4)];
gstattable3 = [1 wmean(1) wstd(1) wmode(1) wmedian(1) wmin(1)
    wmax(1);2 wmean(2) wstd(2) wmode(2) wmedian(2) wmin(2) wmax(2);3
    wmean(3) wstd(3) wmode(3) wmedian(3) wmin(3) wmax(3);4 wmean(4)
    wstd(4) wmode(4) wmedian(4) wmin(4) wmax(4)];

```

---

---

```

gstattable4 = [1 dmean(1) dstd(1) dmode(1) dmedian(1) dmin(1)
dmax(1);2 dmean(2) dstd(2) dmode(2) dmedian(2) dmin(2) dmax(2);3
dmean(3) dstd(3) dmode(3) dmedian(3) dmin(3) dmax(3);4 dmean(4)
dstd(4) dmode(4) dmedian(4) dmin(4) dmax(4)];
```

% Display in tables

```

LegacyODStats = array2table(gstattable1, 'VariableNames',
{'Tray', 'ODMn_mm', 'ODSTD_mm', 'ODMd_mm', 'ODMed_mm', 'ODMin_mm', 'ODMax_mm'});
LegacyHStats = array2table(gstattable2, 'VariableNames',
{'Tray', 'HMn_mm', 'HSTD_mm', 'HMD_mm', 'HMed_mm', 'HMin_mm', 'HMax_mm'});
LegacyWStats = array2table(gstattable3, 'VariableNames',
{'Tray', 'WMn_g', 'WSTD_g', 'WMd_g', 'WMed_g', 'WMin_g', 'WMax_g'});
LegacyDStats = array2table(gstattable4, 'VariableNames',
{'Tray', 'DMn_g_per_cc', 'DSTD_g_per_cc', 'DMd_g_per_cc', 'DMed_g_per_cc', 'DMin_g_per_cc'});
```

% Legacy Total Population Values, Tabulated

```

pstattable1 = {[{'Mean'} odlmean hlmean wlmean dlmean; {'STD'} odlstd
hlstd wlstd dlstd; {'Mode'} odlmode hlmode wlmode dlmode; {'Median'}
odlmedian hlmedian wlmedian dlmedian; {'Min'} odlmin hlmin wlmin
dlmin; {'Max'} odlmax hlmax wlmax dlmax];
LegacyPopStats = cell2table(pstattable1, 'VariableNames',
{'Parameter', 'OD_mm', 'H_mm', 'W_g', 'D_g_per_cc'})}
```

*LegacyTray1Stats =*

6x5 table

Parameter	OD_mm	H_mm	W_g	D_g_per_cc
'Mean'	3.02	3.1749	0.037457	1.647
'STD'	4.486e-16	0.0039684	0.00014147	0.0064526
'Mode'	3.02	3.175	0.03745	1.6472
'Median'	3.02	3.175	0.03745	1.6471
'Min'	3.02	3.162	0.0371	1.6318
'Max'	3.02	3.184	0.0378	1.6667

*LegacyTray2Stats =*

6x5 table

Parameter	OD_mm	H_mm	W_g	D_g_per_cc
'Mean'	3.02	3.1755	0.037492	1.6482
'STD'	4.486e-16	0.0016315	0.00019482	0.0084176
'Mode'	3.02	3.177	0.03748	1.6445
'Median'	3.02	3.176	0.03748	1.6475
'Min'	3.02	3.172	0.03644	1.6028
'Max'	3.02	3.179	0.03778	1.6604

---

```
LegacyTray3Stats =
```

```
6x5 table
```

Parameter	OD_mm	H_mm	W_g	D_g_per_cc
'Mean'	3.02	3.1759	0.037467	1.647
'STD'	4.486e-16	0.0017498	0.00010624	0.0047867
'Mode'	3.02	3.175	0.03745	1.6467
'Median'	3.02	3.176	0.03745	1.646
'Min'	3.02	3.172	0.03723	1.636
'Max'	3.02	3.18	0.03776	1.6619

```
LegacyTray4Stats =
```

```
6x5 table
```

Parameter	OD_mm	H_mm	W_g	D_g_per_cc
'Mean'	3.02	3.1743	0.037529	1.6505
'STD'	4.486e-16	0.0015811	8.3467e-05	0.0036135
'Mode'	3.02	3.174	0.0375	1.6494
'Median'	3.02	3.174	0.03751	1.65
'Min'	3.02	3.17	0.03738	1.6439
'Max'	3.02	3.177	0.03769	1.6578

```
LegacyODStats =
```

```
4x7 table
```

Tray ODMax_mm	ODMn_mm	ODSTD_mm	ODMd_mm	ODMed_mm	ODMin_mm
1 3.02	3.02	4.486e-16	3.02	3.02	3.02
2 3.02	3.02	4.486e-16	3.02	3.02	3.02
3 3.02	3.02	4.486e-16	3.02	3.02	3.02
4 3.02	3.02	4.486e-16	3.02	3.02	3.02

```
LegacyHStats =
```

```
4x7 table
```

---

<i>Tray</i>	<i>HMn_mm</i>	<i>HSTD_mm</i>	<i>HMd_mm</i>	<i>HMed_mm</i>	<i>HMin_mm</i>
<i>HMax_mm</i>	—	—	—	—	—
	—	—	—	—	—
1 3.184	3.1749	0.0039684	3.175	3.175	3.162
2 3.179	3.1755	0.0016315	3.177	3.176	3.172
3 3.18	3.1759	0.0017498	3.175	3.176	3.172
4 3.177	3.1743	0.0015811	3.174	3.174	3.17

*LegacyWStats* =

4×7 table

<i>Tray</i>	<i>WMn_g</i>	<i>WSTD_g</i>	<i>WMd_g</i>	<i>WMed_g</i>	<i>WMin_g</i>
<i>WMax_g</i>	—	—	—	—	—
	—	—	—	—	—
1 0.0378	0.037457	0.00014147	0.03745	0.03745	0.0371
2 0.03778	0.037492	0.00019482	0.03748	0.03748	0.03644
3 0.03776	0.037467	0.00010624	0.03745	0.03745	0.03723
4 0.03769	0.037529	8.3467e-05	0.0375	0.03751	0.03738

*LegacyDStats* =

4×7 table

<i>Tray</i>	<i>DMn_g_per_cc</i>	<i>DSTD_g_per_cc</i>	<i>DMd_g_per_cc</i>	<i>DMed_g_per_cc</i>
<i>DMed_g_per_cc</i>	—	—	—	—
	—	—	—	—
1 1.6318	1.647	0.0064526	1.6472	1.6471
2 1.6028	1.6482	0.0084176	1.6445	1.6475
3 1.636	1.647	0.0047867	1.6467	1.646
4 1.6439	1.6505	0.0036135	1.6494	1.65
	1.6578			

*LegacyPopStats* =

---

6x5 table

Parameter	OD_mm	H_mm	W_g	D_g_per_cc
'Mean'	3.02	3.1752	0.037486	1.6482
'STD'	8.4589e-15	0.0025025	0.00013984	0.0062162
'Mode'	3.02	3.174	0.03745	1.6467
'Median'	3.02	3.175	0.037475	1.6478
'Min'	3.02	3.162	0.03644	1.6028
'Max'	3.02	3.184	0.0378	1.6667

## Legacy Data Histograms

Legacy Height, default bins (10)

```
figure('name','Legacy Height Histograms, 10 Bins')
subplot(2,2,1)
histfit(h(:,1))
title('Legacy Height, Tray 1, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,2)
histfit(h(:,2))
title('Legacy Height, Tray 2, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,3)
histfit(h(:,3))
title('Legacy Height, Tray 3, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,4)
histfit(h(:,4))
title('Legacy Height, Tray 4, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on

% Legacy Height, 2x bins (20)
```

---

```
figure('name','Legacy Height Histograms, 20 Bins')
subplot(2,2,1)
histfit(h(:,1),20)
title('Legacy Height, Tray 1, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,2)
histfit(h(:,2),20)
title('Legacy Height, Tray 2, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,3)
histfit(h(:,3),20)
title('Legacy Height, Tray 3, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,4)
histfit(h(:,4),20)
title('Legacy Height, Tray 4, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on

% Legacy Weight, default bins (10)
figure('name','Legacy Weight Histograms, 10 Bins')
subplot(2,2,1)
histfit(w(:,1))
title('Legacy Weight, Tray 1, 10 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,2)
histfit(w(:,2))
title('Legacy Weight, Tray 2, 10 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,3)
histfit(w(:,3))
```

---

```
title('Legacy Weight, Tray 3, 10 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,4)
histfit(w(:,4))
title('Legacy Weight, Tray 4, 10 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on

% Legacy Weight, 2x bins (20)
figure('name','Legacy Weight Histograms, 20 Bins')
subplot(2,2,1)
histfit(w(:,1),20)
title('Legacy Weight, Tray 1, 20 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,2)
histfit(w(:,2),20)
title('Legacy Weight, Tray 2, 20 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,3)
histfit(w(:,3),20)
title('Legacy Weight, Tray 3, 20 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(2,2,4)
histfit(w(:,4),20)
title('Legacy Weight, Tray 4, 20 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on

% Legacy Density, default bins (10)
figure('name','Legacy Density Histograms, 10 Bins')
subplot(2,2,1)
histfit(d(:,1))
```

---

```

title('Legacy Density, Tray 1, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on
subplot(2,2,1)
histfit(d(:,1))
title('Legacy Density, Tray 2, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on
subplot(2,2,2)
histfit(d(:,2))
title('Legacy Density, Tray 3, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on
subplot(2,2,3)
histfit(d(:,3))
title('Legacy Density, Tray 4, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on

% Legacy Density, 2x bins (20)
figure('name','Legacy Density Histograms, 20 Bins')
subplot(2,2,1)
histfit(d(:,1),20)
title('Legacy Density, Tray 1, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on
subplot(2,2,2)
histfit(d(:,2),20)
title('Legacy Density, Tray 2, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on
subplot(2,2,3)
histfit(d(:,3),20)
title('Legacy Density, Tray 3, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])

```

---

---

```

ylabel('# of Pellets')
ylim([0 35])
grid on
subplot(2,2,4)
histfit(d(:,4),20)
title('Legacy Density, Tray 4, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on

% Legacy Total Population Values, default bins (10)
figure('name','Legacy Total Population Histograms, 10 Bins')
subplot(3,1,1)
histfit(hl)
title('Legacy Total Population Height, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,1,2)
histfit(wl)
title('Legacy Total Population Weight, 10 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,1,3)
histfit(dl)
title('Legacy Total Population Density, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 100])
grid on

% Legacy Total Population Values, 2x bins (20)
figure('name','Legacy Total Population Histograms, 20 Bins')
subplot(3,1,1)
histfit(hl,20)
title('Legacy Total Population Height, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,1,2)
histfit(wl,20)
title('Legacy Total Population Weight, 20 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])

```

---

---

```

ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,1,3)
histfit(dl,20)
title('Legacy Total Polulation Density, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 100])
grid on

% Re-plot Tray 1 Parameters in one figure for report
figure('name','Legacy Tray 1 Histograms, 10 Bins')
subplot(3,1,1)
histfit(h(:,1))
title('Legacy Height, Tray 1, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(3,1,2)
histfit(w(:,1))
title('Legacy Weight, Tray 1, 10 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(3,1,3)
histfit(d(:,1))
title('Legacy Density, Tray 1, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on

figure('name','Legacy Tray 1 Histograms, 20 Bins')
subplot(3,1,1)
histfit(h(:,1),20)
title('Legacy Height, Tray 1, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(3,1,2)
histfit(w(:,1),20)
title('Legacy Weight, Tray 1, 20 Bins')
xlabel('Weight (g)')
xlim([0.0362 0.0382])
ylabel('# of Pellets')

```

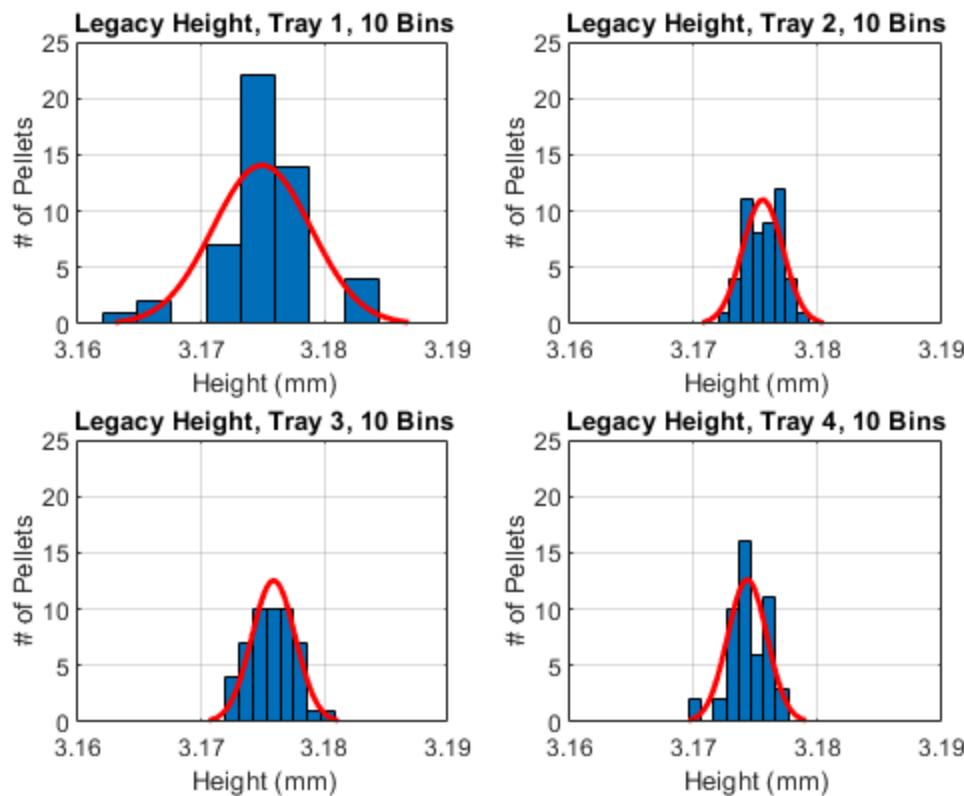
---

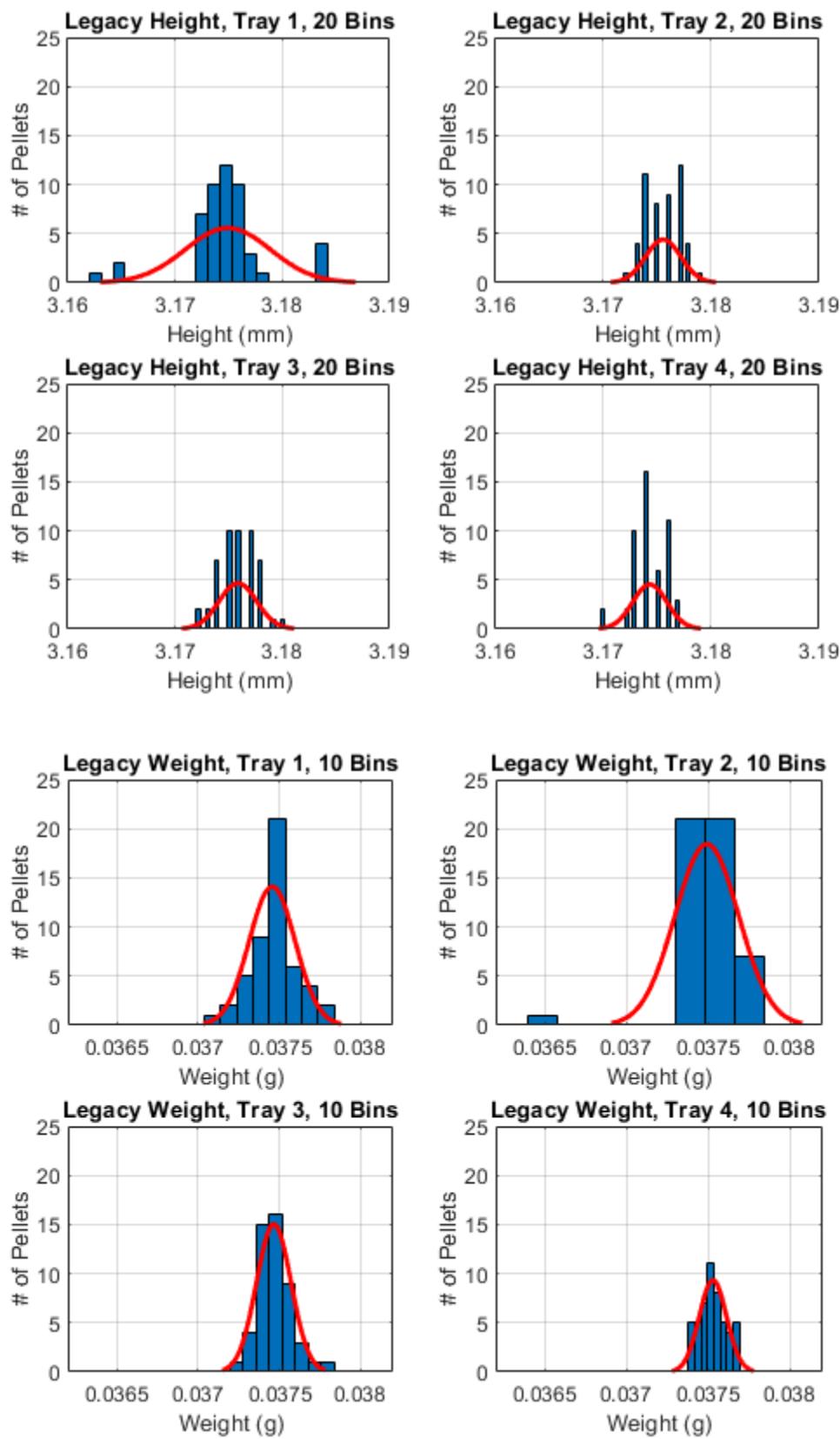
---

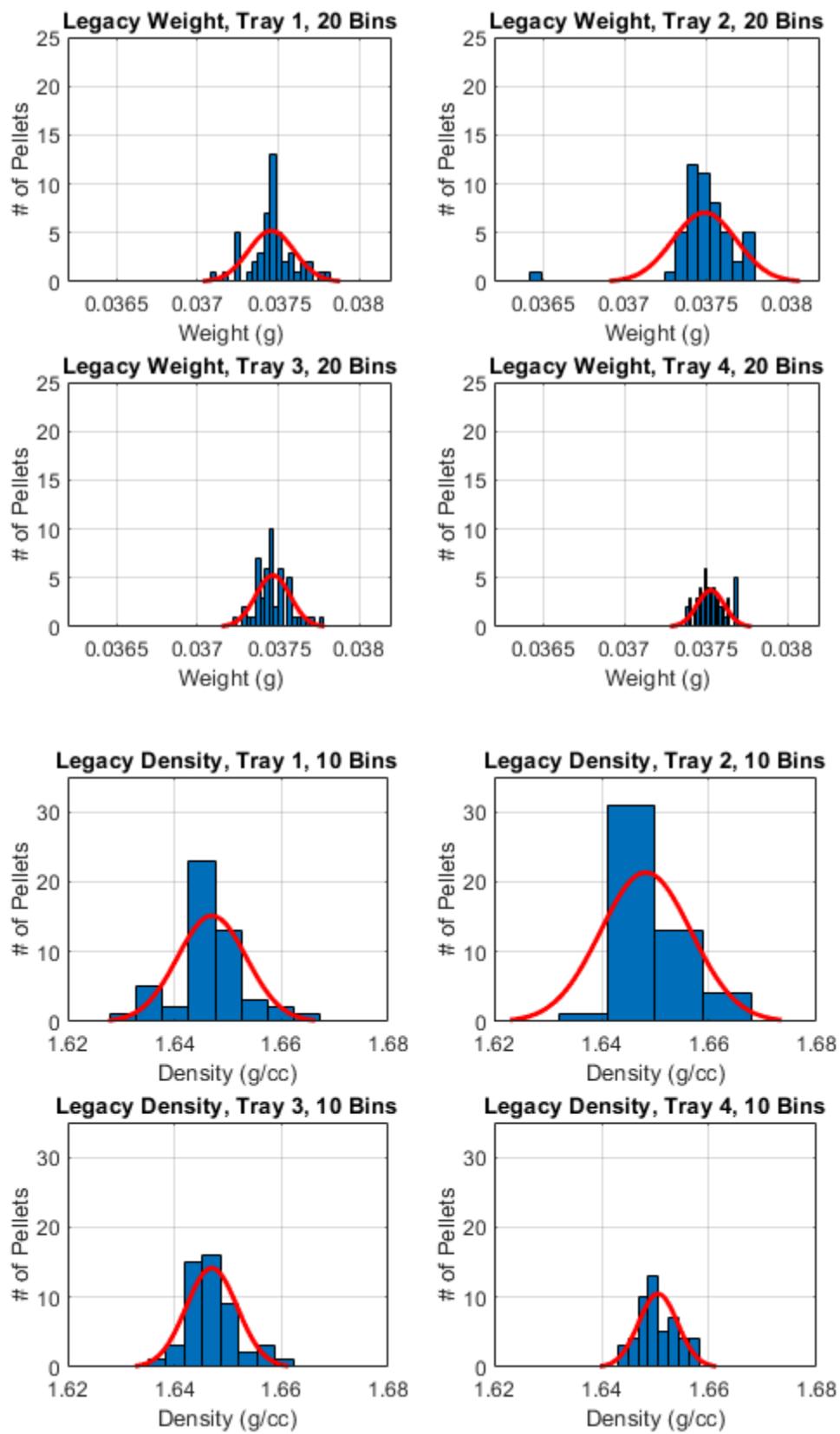
```

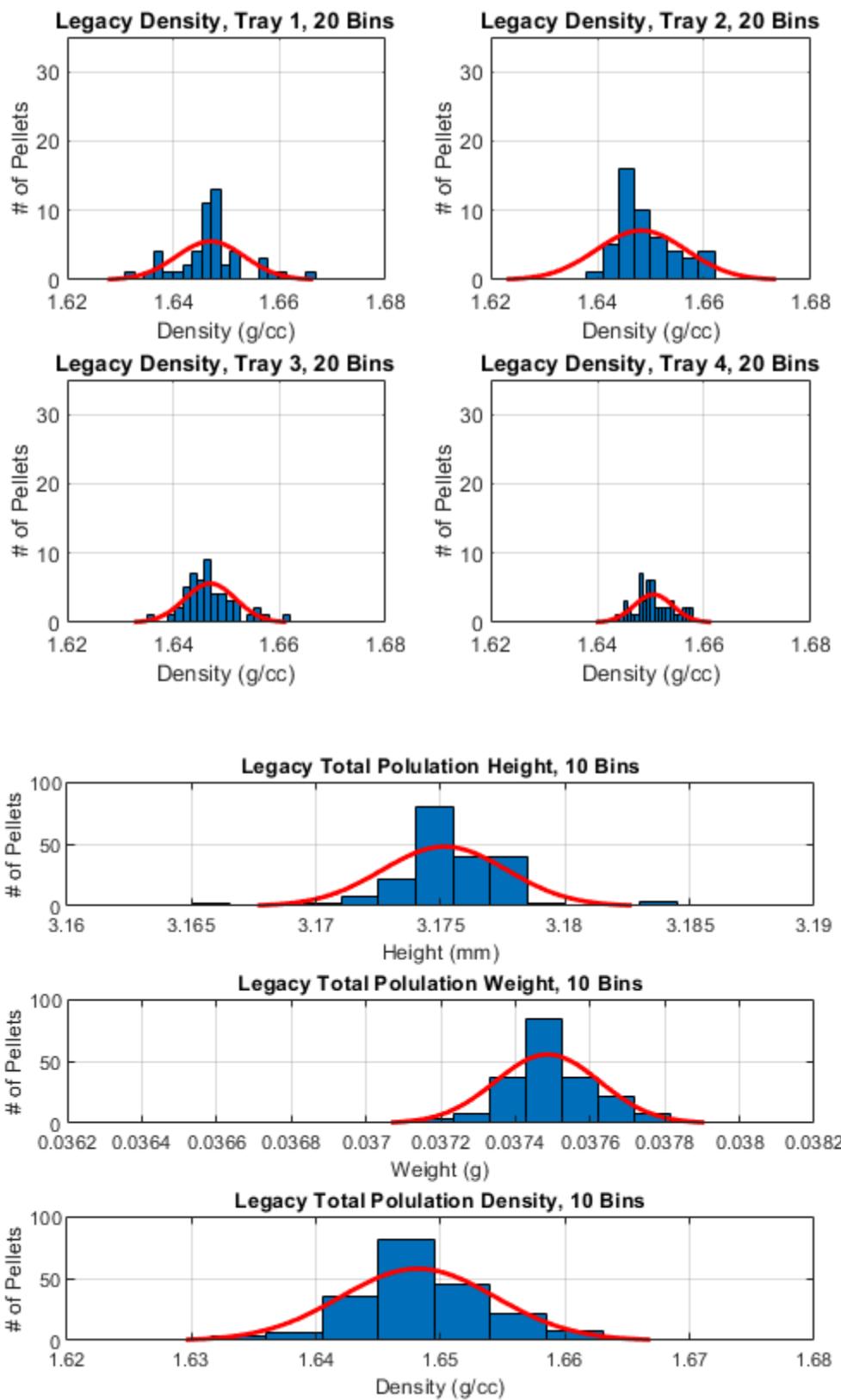
ylim([0 25])
grid on
subplot(3,1,3)
histfit(d(:,1),20)
title('Legacy Density, Tray 1, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.62 1.68])
ylabel('# of Pellets')
ylim([0 35])
grid on

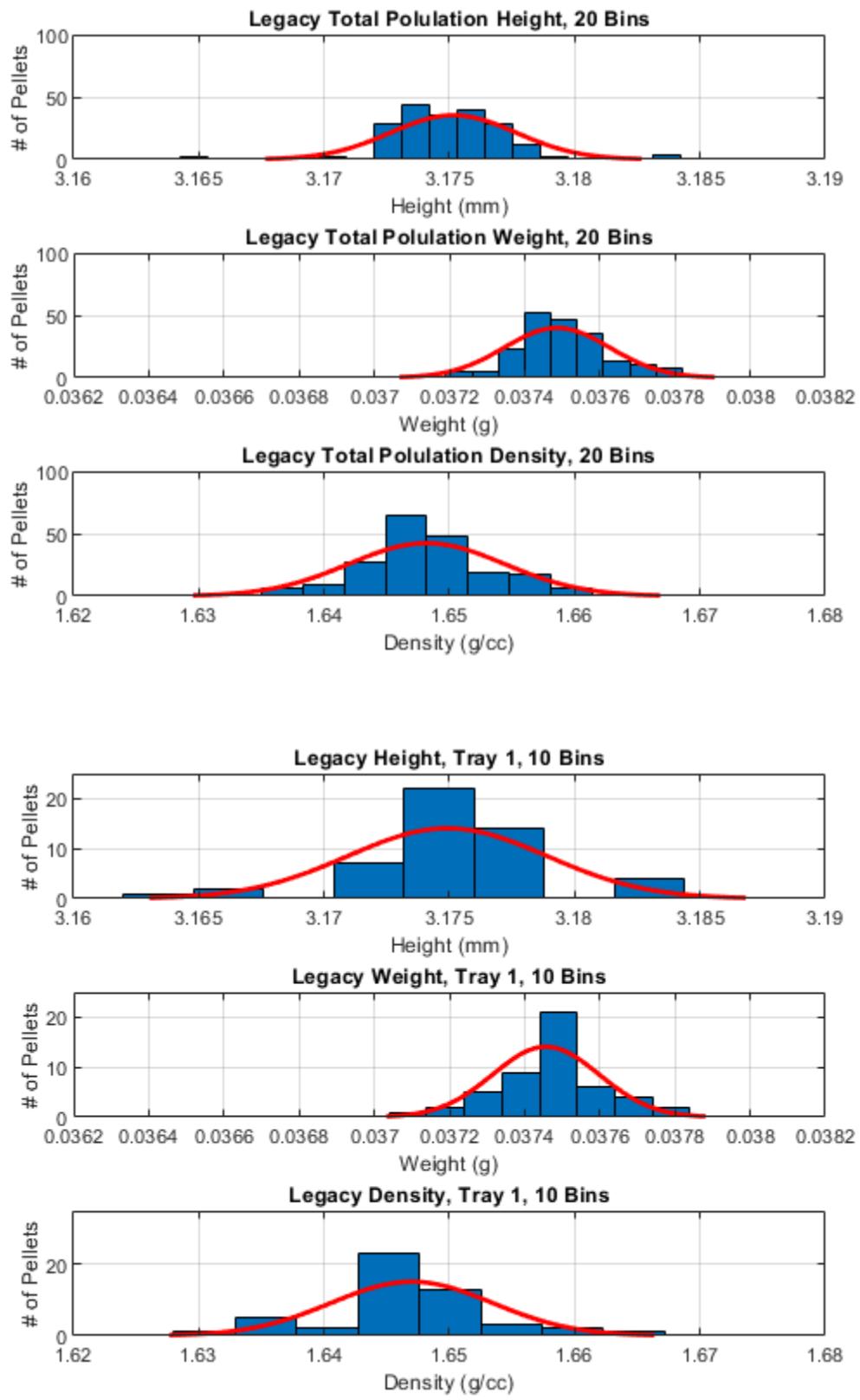
```

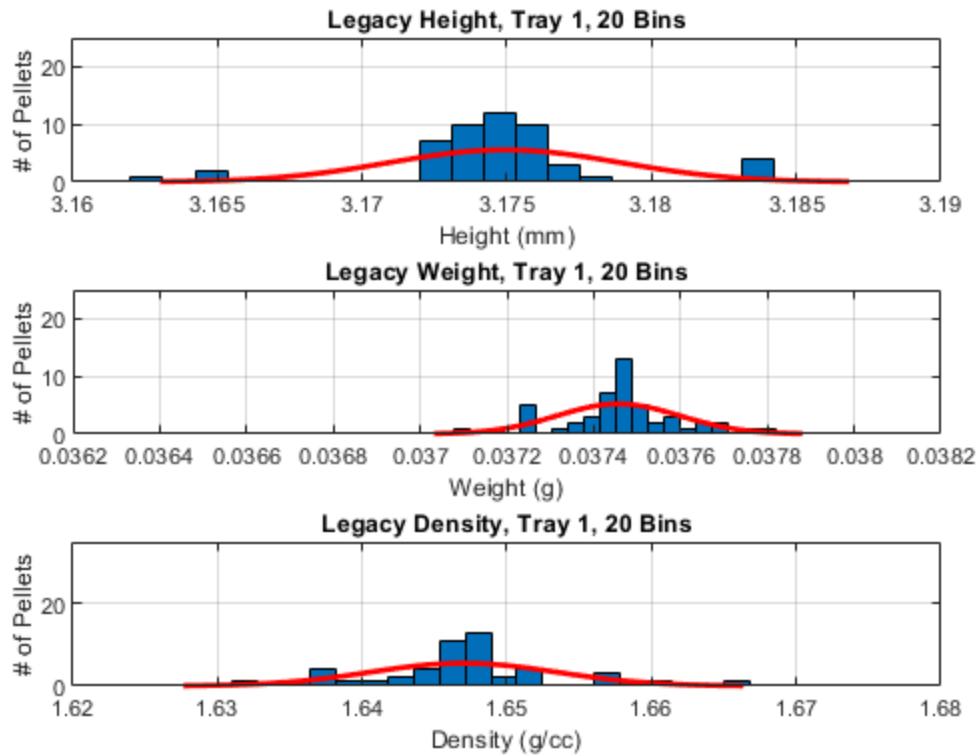












## Legacy Data Testing

Parameter by tray Legacy OD

```
[odt1,odpt1,odst1] = chi2gof(od(:,1)); % chisquare test
[odt2,odpt2,odst2] = chi2gof(od(:,2));
[odt3,odpt3,odst3] = chi2gof(od(:,3));
[odt4,odpt4,odst4] = chi2gof(od(:,4));

% Legacy Height
[ht1,hpt1,hst1] = chi2gof(h(:,1));
[ht2,hpt2,hst2] = chi2gof(h(:,2));
[ht3,hpt3,hst3] = chi2gof(h(:,3));
[ht4,hpt4,hst4] = chi2gof(h(:,4));

% Legacy Weight
[wt1,wpt1,wst1] = chi2gof(w(:,1));
[wt2,wpt2,wst2] = chi2gof(w(:,2));
[wt3,wpt3,wst3] = chi2gof(w(:,3));
[wt4,wpt4,wst4] = chi2gof(w(:,4));

% Legacy Density
[dt1,dpt1,dst1] = chi2gof(d(:,1));
[dt2,dpt2,dst2] = chi2gof(d(:,2));
[dt3,dpt3,dst3] = chi2gof(d(:,3));
[dt4,dpt4,dst4] = chi2gof(d(:,4));
```

---

```

% All values from Legacy Data by Parameter
[odl1,odlp1,odls1] = chi2gof(odl); % chisquare test
[h11,hlp1,hls1] = chi2gof(hl);
[w11,wlp1,wls1] = chi2gof(wl);
[d11,dlp1,dls1] = chi2gof(dl);

odtraytest = [{ '0/1' } odt1 odt2 odt3 odt4;{'pvalue'} odpt1 odpt2 odpt3
odpt4];
LegacyODTestStats = cell2table(odtraytest,'VariableNames',
{'Hypothesis','Tray1','Tray2','Tray3','Tray4'})

htraytest = [{ '0/1' } ht1 ht2 ht3 ht4;{'pvalue'} hpt1 hpt2 hpt3 hpt4];
LegacyHTestStats = cell2table(htraytest,'VariableNames',
{'Hypothesis','Tray1','Tray2','Tray3','Tray4'})

wtraytest = [{ '0/1' } wt1 wt2 wt3 wt4;{'pvalue'} wpt1 wpt2 wpt3 wpt4];
LegacyWTestStats = cell2table(wtraytest,'VariableNames',
{'Hypothesis','Tray1','Tray2','Tray3','Tray4'})

dtraytest = [{ '0/1' } dt1 dt2 dt3 dt4;{'pvalue'} dpt1 dpt2 dpt3 dpt4];
LegacyDTestStats = cell2table(dtraytest,'VariableNames',
{'Hypothesis','Tray1','Tray2','Tray3','Tray4'})

Poptest = [{ '0/1' } od11 hl1 wl1 dl1;{'pvalue'} odlp1 hlp1 wlp1 dlp1];
LegacyPopTestStats = cell2table(Poptest,'VariableNames',
{'Hypothesis','OD','H','W','D'})

Warning: After pooling, some bins still have low expected counts.
The chi-square approximation may not be accurate
Warning: After pooling, some bins still have low expected counts.
The chi-square approximation may not be accurate
Warning: After pooling, some bins still have low expected counts.
The chi-square approximation may not be accurate
Warning: After pooling, some bins still have low expected counts.
The chi-square approximation may not be accurate
Warning: After pooling, some bins still have low expected counts.
The chi-square approximation may not be accurate
Warning: After pooling, some bins still have low expected counts.
The chi-square approximation may not be accurate

LegacyODTestStats =

```

2x5 table

Hypothesis	Tray1	Tray2	Tray3	Tray4
'0/1'	0	0	0	0
'pvalue'	NaN	NaN	NaN	NaN

```

LegacyHTestStats =

```

2x5 table

---

<i>Hypothesis</i>	<i>Tray1</i>	<i>Tray2</i>	<i>Tray3</i>	<i>Tray4</i>
'0/1'	1	1	1	1
'pvalue'	7.6876e-05	3.7256e-05	0.01028	1.6893e-05

*LegacyWTestStats* =

2×5 table

<i>Hypothesis</i>	<i>Tray1</i>	<i>Tray2</i>	<i>Tray3</i>	<i>Tray4</i>
'0/1'	0	1	0	0
'pvalue'	0.051421	0.0013372	0.69114	0.59739

*LegacyDTestStats* =

2×5 table

<i>Hypothesis</i>	<i>Tray1</i>	<i>Tray2</i>	<i>Tray3</i>	<i>Tray4</i>
'0/1'	1	1	0	0
'pvalue'	0.00017105	0.00062707	0.36948	0.23446

*LegacyPopTestStats* =

2×5 table

<i>Hypothesis</i>	<i>OD</i>	<i>H</i>	<i>W</i>	<i>D</i>
'0/1'	0	1	1	1
'pvalue'	NaN	0.0011509	0.00071731	0.010882

## Legacy Data Machine Sorting and Dendograms

Legacy Height Euclidean Dendograms

```
ytesth1 = pdist(h(:,1)); % tray 1
squareform(ytesth1);
ztesth1 = linkage(ytesth1);
ytesth2 = pdist(h(:,2)); % tray 2
squareform(ytesth2);
ztesth2 = linkage(ytesth2);
```

---

```

ytesth3 = pdist(h(:,3)); % tray 3
squareform(ytesth3);
ztesth3 = linkage(ytesth3);
ytesth4 = pdist(h(:,4)); % tray 4
squareform(ytesth4);
ztesth4 = linkage(ytesth4);
ytestht = pdist(hl(:,1)); % total population
squareform(ytestht);
ztestht = linkage(ytestht);

figure ('name','Legacy Height Euclidean Dendograms by Tray')
subplot(2,2,1)
dendrogram(ztesth1,0)
title('Legacy Height, Tray 1, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])
subplot(2,2,2)
dendrogram(ztesth2,0)
title('Legacy Height, Tray 2, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])
subplot(2,2,3)
dendrogram(ztesth3,0)
title('Legacy Height, Tray 3, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])
subplot(2,2,4)
dendrogram(ztesth4,0)
title('Legacy Height, Tray 4, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

figure ('name','Legacy Height Euclidean Dendograms, All Pellets')
dendrogram(ztestht,0)
title('Legacy Height, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

% Legacy Height Cityblock Dendograms
ytesth1cb = pdist(h(:,1),'cityblock'); % tray 1
squareform(ytesth1cb);
ztesth1cb = linkage(ytesth1cb,'average');
ytesth2cb = pdist(h(:,2),'cityblock'); % tray 2
squareform(ytesth2cb);
ztesth2cb = linkage(ytesth2cb,'average');
ytesth3cb = pdist(h(:,3),'cityblock'); % tray 3
squareform(ytesth3cb);
ztesth3cb = linkage(ytesth3cb,'average');
ytesth4cb = pdist(h(:,4),'cityblock'); % tray 4

```

---

---

```

squareform(ytesth4cb);
ztesth4cb = linkage(ytesth4cb,'average');
ytesthtcb = pdist(hl(:,1),'cityblock'); % total population
squareform(ytesthtcb);
ztesthtcb = linkage(ytesthtcb,'average');

figure ('name','Legacy Height Cityblock Dendrograms by Tray')
subplot(2,2,1)
dendrogram(ztesth1cb,0)
title('Legacy Height, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])
subplot(2,2,2)
dendrogram(ztesth2cb,0)
title('Legacy Height, Tray 2, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])
subplot(2,2,3)
dendrogram(ztesth3cb,0)
title('Legacy Height, Tray 3, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])
subplot(2,2,4)
dendrogram(ztesth4cb,0)
title('Legacy Height, Tray 4, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

figure ('name','Legacy Height Cityblock Dendrograms, All Pellets')
dendrogram(ztesthtcb,0)
title('Legacy Height, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

% Legacy Weight Euclidean Dendrograms
ytestw1 = pdist(w(:,1)); % tray 1
squareform(ytestw1);
ztestw1 = linkage(ytestw1);
ytestw2 = pdist(w(:,2)); % tray 2
squareform(ytestw2);
ztestw2 = linkage(ytestw2);
ytestw3 = pdist(w(:,3)); % tray 3
squareform(ytestw3);
ztestw3 = linkage(ytestw3);
ytestw4 = pdist(w(:,4)); % tray 4
squareform(ytestw4);
ztestw4 = linkage(ytestw4);
ytestwt = pdist(wl(:,1)); % total population
squareform(ytestwt);

```

---

---

```

ztestwt = linkage(ytestwt);

figure ('name','Legacy Weight Euclidean Dendograms by Tray')
subplot(2,2,1)
dendrogram(ztestw1,0)
title('Legacy Weight, Tray 1, Euclidean')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])
subplot(2,2,2)
dendrogram(ztestw2,0)
title('Legacy Weight, Tray 2, Euclidean')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])
subplot(2,2,3)
dendrogram(ztestw3,0)
title('Legacy Weight, Tray 3, Euclidean')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])
subplot(2,2,4)
dendrogram(ztestw4,0)
title('Legacy Weight, Tray 4, Euclidean')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

figure ('name','Legacy Weight Euclidean Dendrogram, All Pellets')
dendrogram(ztestwt,0)
title('Legacy Weight, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

% Legacy Weight Cityblock Dendograms
ytestw1cb = pdist(w(:,1),'cityblock'); % tray 1
squareform(ytestw1cb);
ztestw1cb = linkage(ytestw1cb,'average');
ytestw2cb = pdist(w(:,2),'cityblock'); % tray 2
squareform(ytestw2cb);
ztestw2cb = linkage(ytestw2cb,'average');
ytestw3cb = pdist(w(:,3),'cityblock'); % tray 3
squareform(ytestw3cb);
ztestw3cb = linkage(ytestw3cb,'average');
ytestw4cb = pdist(w(:,4),'cityblock'); % tray 4
squareform(ytestw4cb);
ztestw4cb = linkage(ytestw4cb,'average');
ytestwtcb = pdist(wl(:,1),'cityblock'); % total population
squareform(ytestwtcb);
ztestwtcb = linkage(ytestwtcb,'average');

figure ('name','Legacy Weight Cityblock Dendograms by Tray')
subplot(2,2,1)

```

---

---

```

dendrogram(ztestw1cb,0)
title('Legacy Weight, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])
subplot(2,2,2)
dendrogram(ztestw2cb,0)
title('Legacy Weight, Tray 2, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])
subplot(2,2,3)
dendrogram(ztestw3cb,0)
title('Legacy Weight, Tray 3, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])
subplot(2,2,4)
dendrogram(ztestw4cb,0)
title('Legacy Weight, Tray 4, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

figure ('name','Legacy Weight Cityblock Dendrogram, All Pellets')
dendrogram(ztestwtcb,0)
title('Legacy Weight, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

% Legacy Density Euclidean Dendograms
ytestd1 = pdist(d(:,1)); % tray 1
squareform(ytestd1);
ztestd1 = linkage(ytestd1);
ytestd2 = pdist(d(:,2)); % tray 2
squareform(ytestd2);
ztestd2 = linkage(ytestd2);
ytestd3 = pdist(d(:,3)); % tray 3
squareform(ytestd3);
ztestd3 = linkage(ytestd3);
ytestd4 = pdist(d(:,4)); % tray 4
squareform(ytestd4);
ztestd4 = linkage(ytestd4);
ytestdt = pdist(dl(:,1)); % total population
squareform(ytestdt);
ztestdt = linkage(ytestdt);

figure ('name','Legacy Density Euclidean Dendograms by Tray')
subplot(2,2,1)
dendrogram(ztestd1,0)
title('Legacy Density, Tray 1, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')

```

---

---

```

set(gca,'xtick',[])
subplot(2,2,2)
dendrogram(ztestd2,0)
title('Legacy Density, Tray 2, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,2,3)
dendrogram(ztestd3,0)
title('Legacy Density, Tray 3, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,2,4)
dendrogram(ztestd4,0)
title('Legacy Density, Tray 4, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

figure ('name','Legacy Density Euclidean Dendrogram, All Pellets')
dendrogram(ztestdt,0)
title('Legacy Density, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

% Legacy Density Cityblock Dendograms
ytestd1cb = pdist(d(:,1),'cityblock'); % tray 1
squareform(ytestd1cb);
ztestd1cb = linkage(ytestd1cb,'average');
ytestd2cb = pdist(d(:,2),'cityblock'); % tray 2
squareform(ytestd2cb);
ztestd2cb = linkage(ytestd2cb,'average');
ytestd3cb = pdist(d(:,3),'cityblock'); % tray 3
squareform(ytestd3cb);
ztestd3cb = linkage(ytestd3cb,'average');
ytestd4cb = pdist(d(:,4),'cityblock'); % tray 4
squareform(ytestd4cb);
ztestd4cb = linkage(ytestd4cb,'average');
ytestdtcb = pdist(dl(:,1),'cityblock'); % total population
squareform(ytestdtcb);
ztestdtcb = linkage(ytestdtcb,'average');

figure ('name','Legacy Density Cityblock Dendograms by Tray')
subplot(2,2,1)
dendrogram(ztestd1cb,0)
title('Legacy Density, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,2,2)
dendrogram(ztestd2cb,0)
title('Legacy Density, Tray 2, Cityblock')

```

---

---

```

xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,2,3)
dendrogram(ztestd3cb,0)
title('Legacy Density, Tray 3, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,2,4)
dendrogram(ztestd4cb,0)
title('Legacy Density, Tray 4, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

figure ('name','Legacy Density Cityblock Dendrogram, All Pellets')
dendrogram(ztestdtcb,0)
title('Legacy Density, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

% Legacy Tray 1 All Parameters, Euclidian
ytestall = pdist(al(1:50,:));
squareform(ytestall);
ztestall = linkage(ytestall);

figure ('name','Legacy Euclidean Dendograms, Tray 1, All Parameters')
dendrogram(ztestall,0)
title('Legacy Tray 1, All Parameters, Euclidean')
xlabel('Pellet Index Number')
ylabel('Difference')
set(gca,'xtick',[])

figure('name','Legacy Tray 1, All Parameters, Euclidean, Close View')
dendrogram(ztestall,0)
title('Legacy Tray 1, All Parameter, Euclidean')
xlabel('Pellet Index Number')
ylabel('Difference (unitless)')
xlim([0 15])
ylim([0 0.0025])

% Legacy Tray 1 All Parameters, Cityblock
ytestallcb = pdist(al(1:50,:),'cityblock');
squareform(ytestallcb);
ztestallcb = linkage(ytestallcb,'average');

figure ('name','Legacy Cityblock Dendograms, Tray 1, All Parameters')
dendrogram(ztestallcb,0)
title('Legacy Tray 1, All Parameters, Cityblock')
xlabel('Pellet Index Number')
ylabel('Difference')
set(gca,'xtick',[])

```

---

---

```

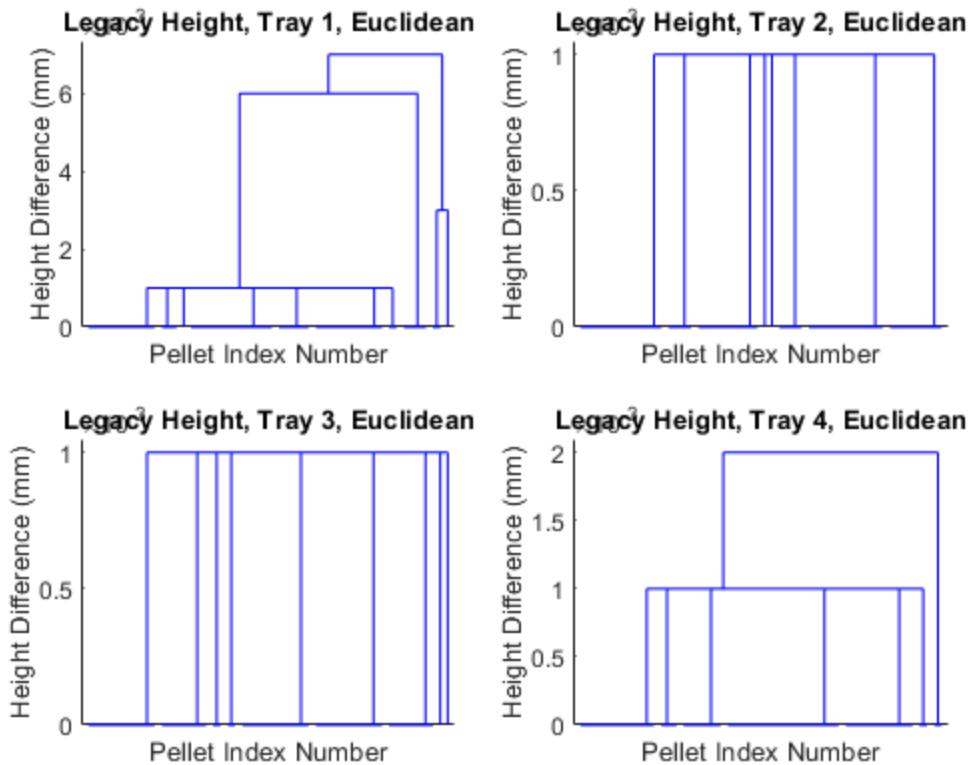
% Legacy Euclidean Dendrograms
ytestal = pdist(al);
squareform(ytestal);
ztestal = linkage(ytestal);

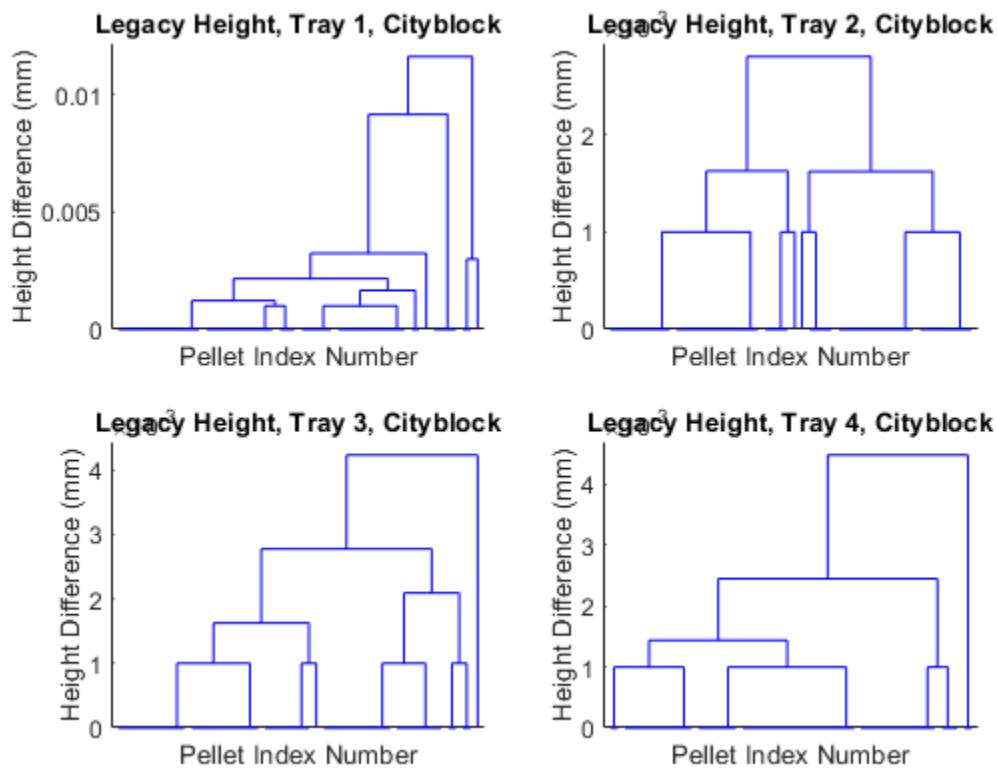
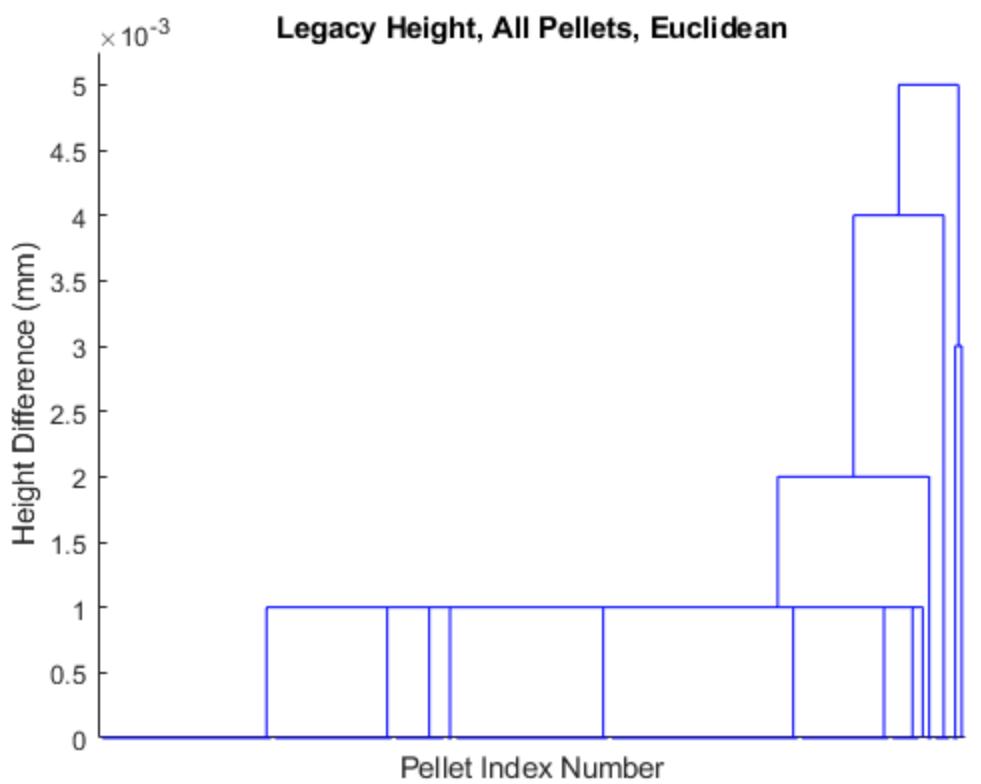
figure ('name','Legacy Euclidean Dendrograms, All Pellets, All
Parameters')
dendrogram(ztestal,0)
title('Legacy All Pellets, All Parameters, Euclidean')
xlabel('Pellet Index Number')
ylabel('Difference')
set(gca,'xtick',[])

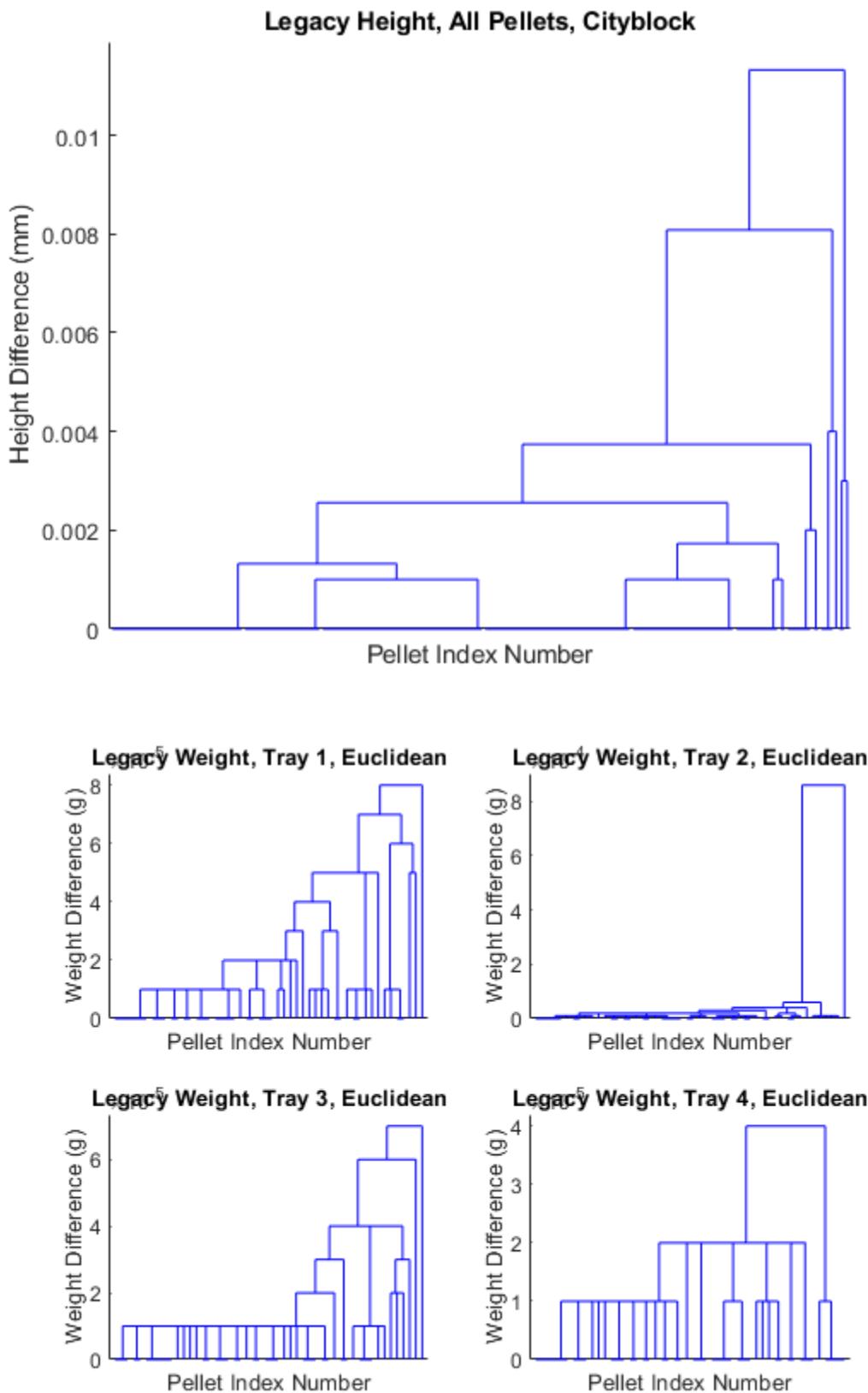
% Legacy Cityblock Dendrograms
ytestalcb = pdist(al, 'cityblock');
squareform(ytestalcb);
ztestalcb = linkage(ytestalcb, 'average');

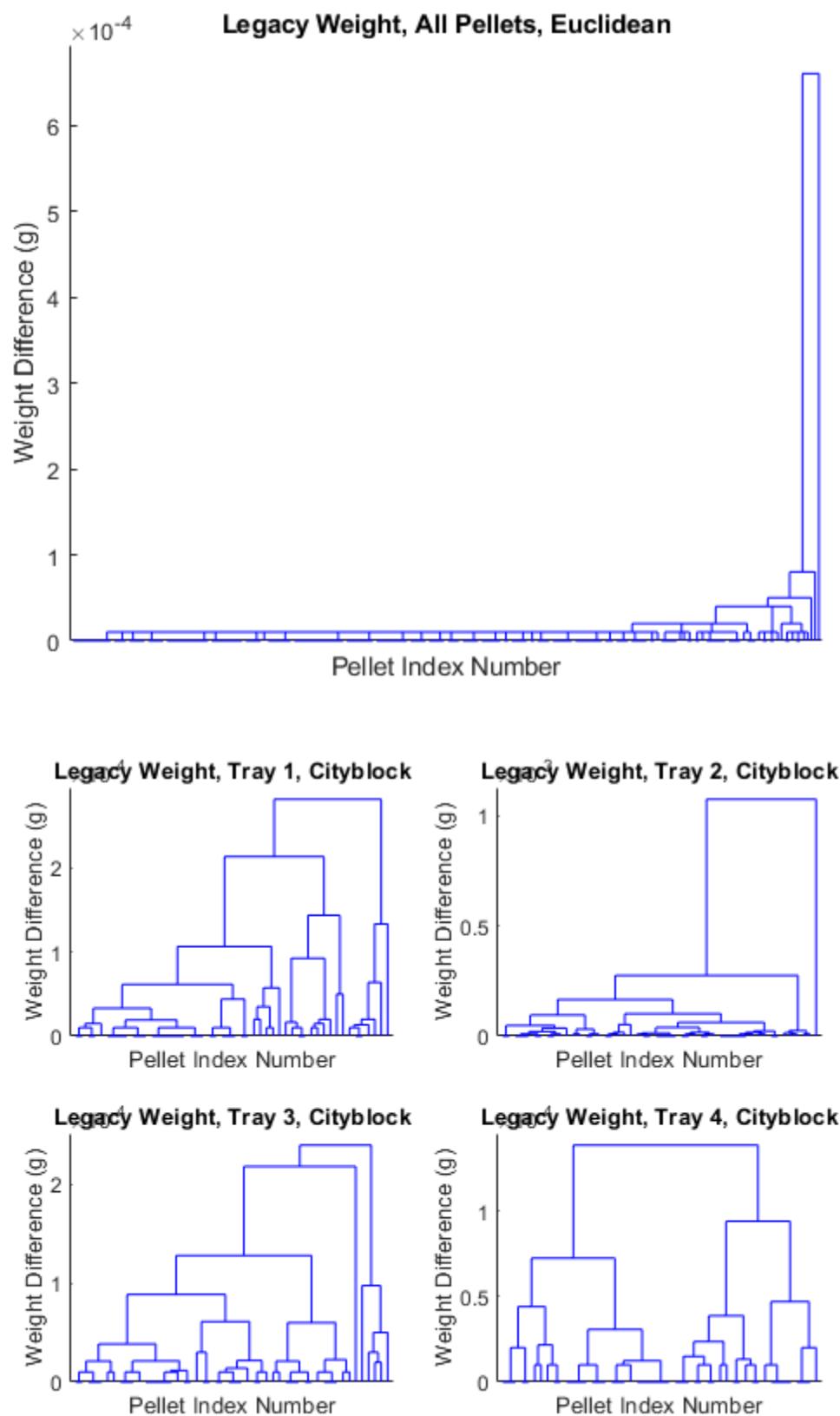
figure ('name','Legacy Cityblock Dendrograms,All Pellets, All
Parameters')
dendrogram(ztestalcb,0)
title('Legacy All Pellets, All Parameters, Cityblock')
xlabel('Pellet Index Number')
ylabel('Difference')
set(gca,'xtick',[])

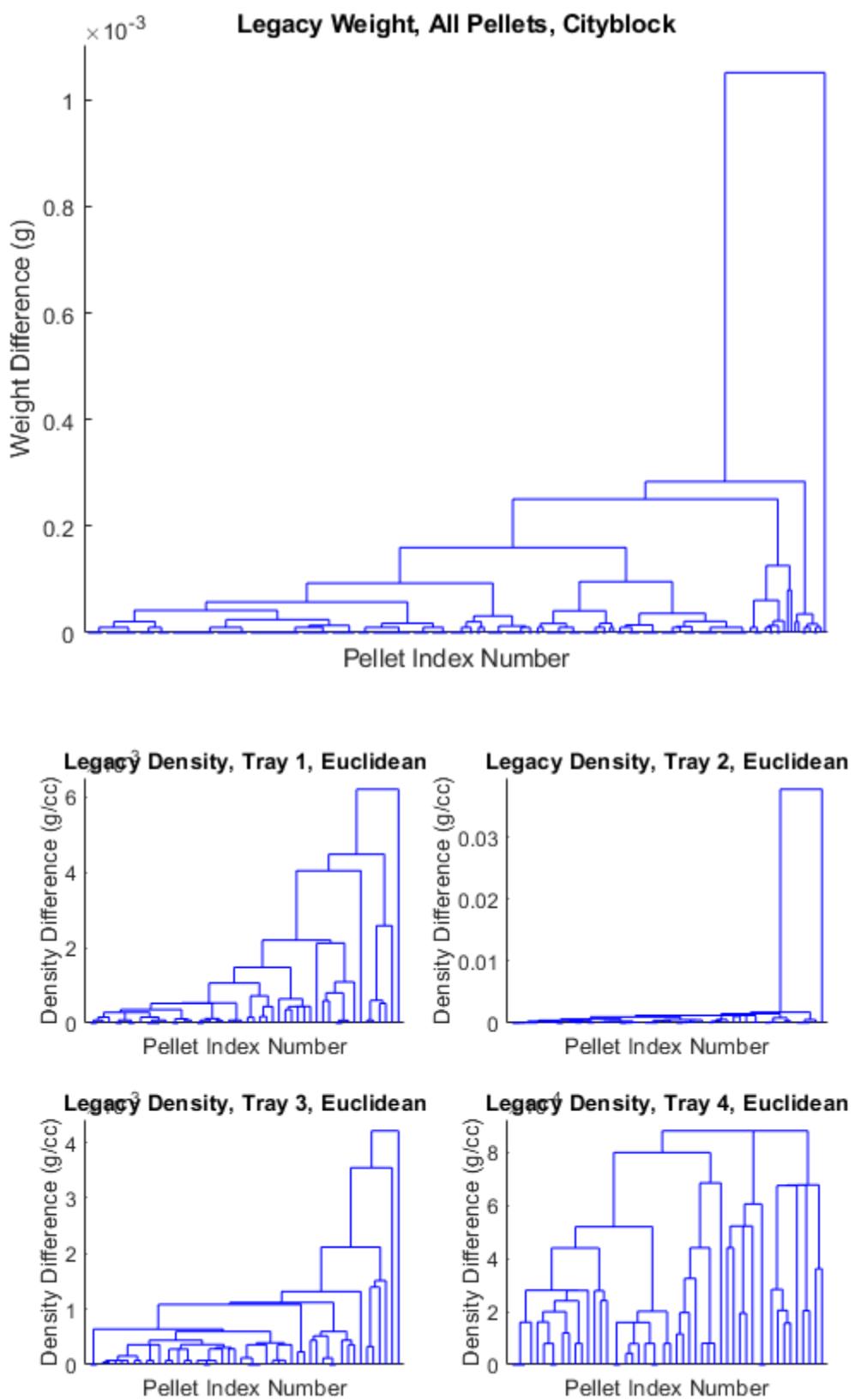
```

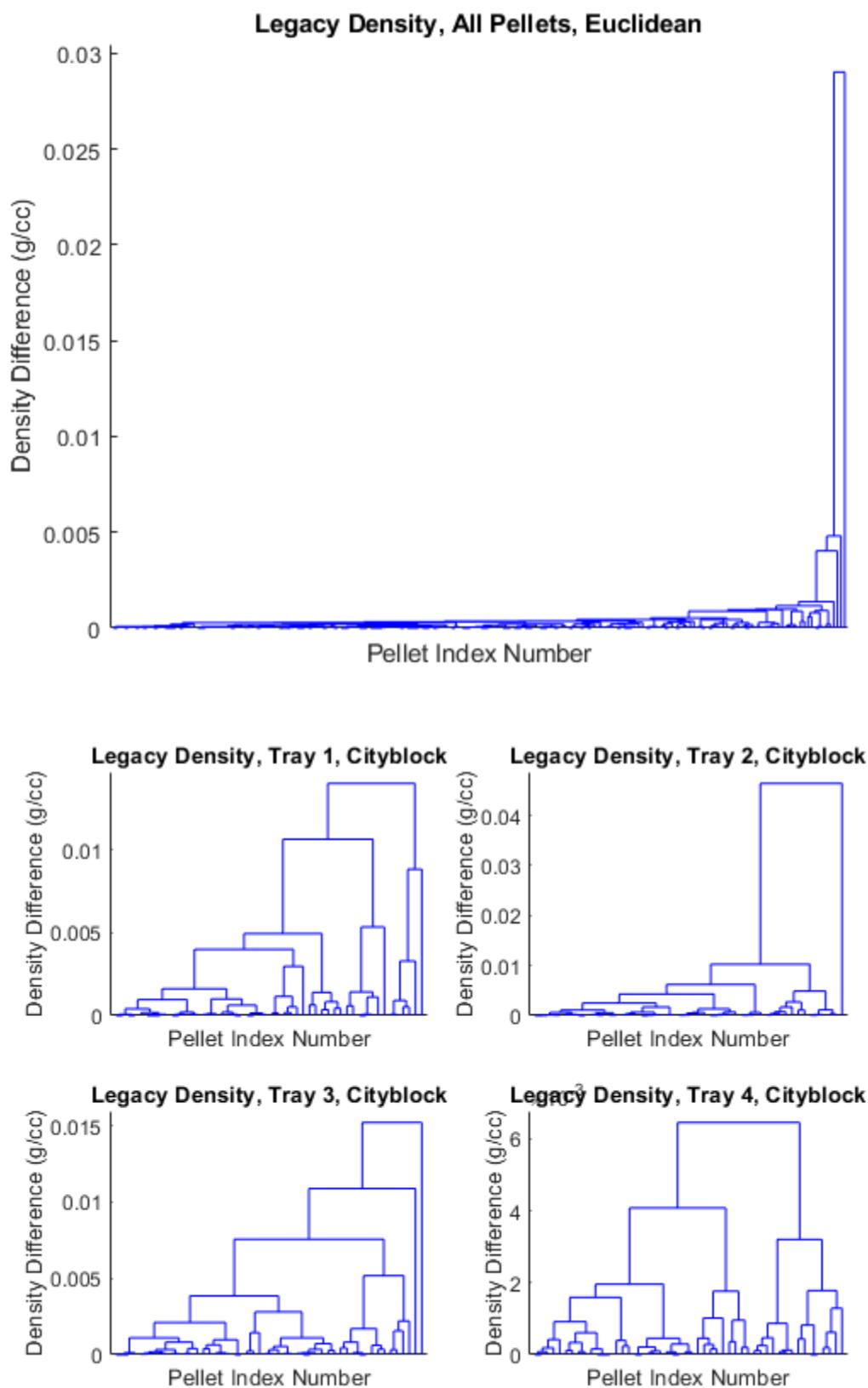


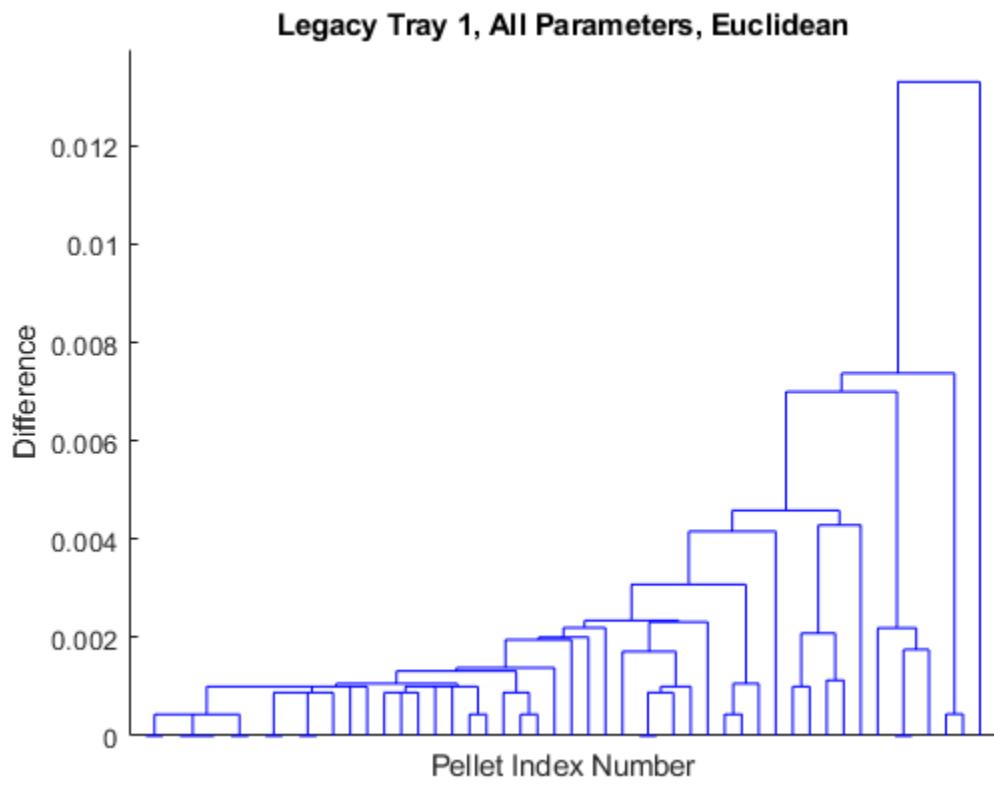
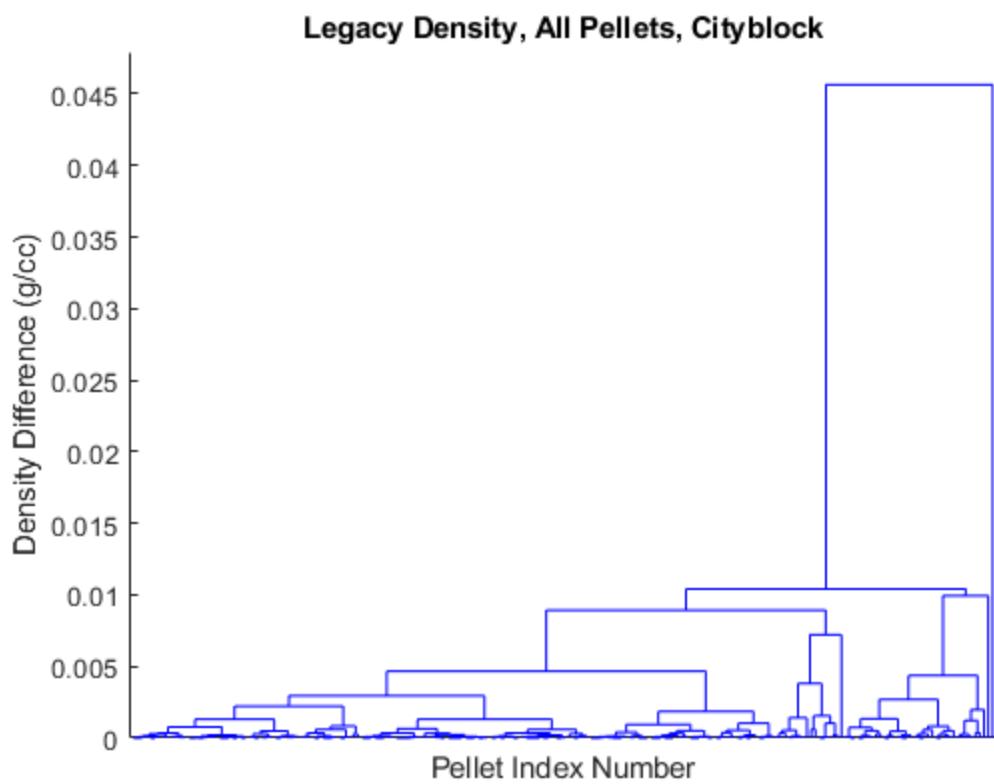


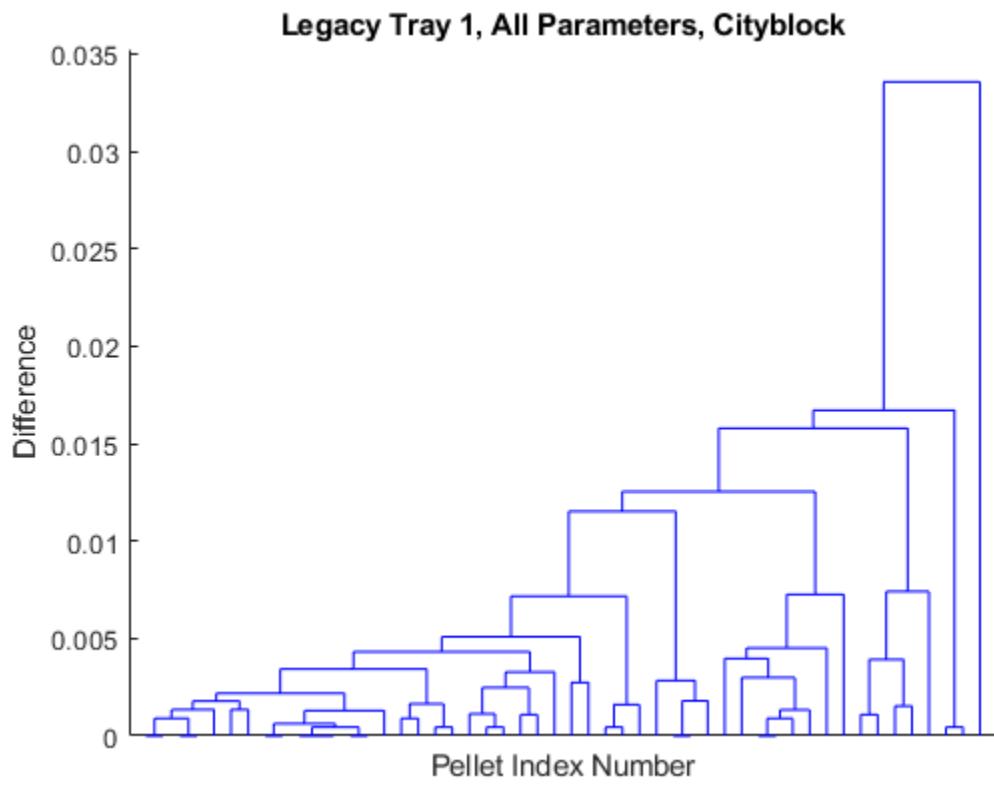
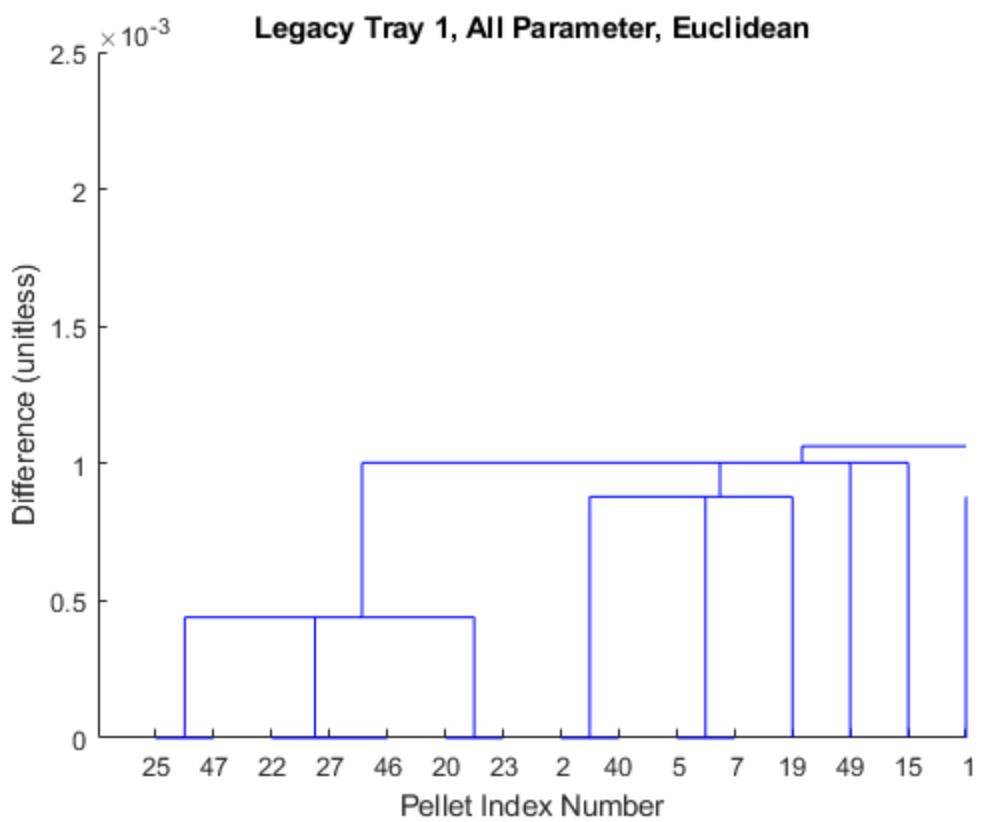


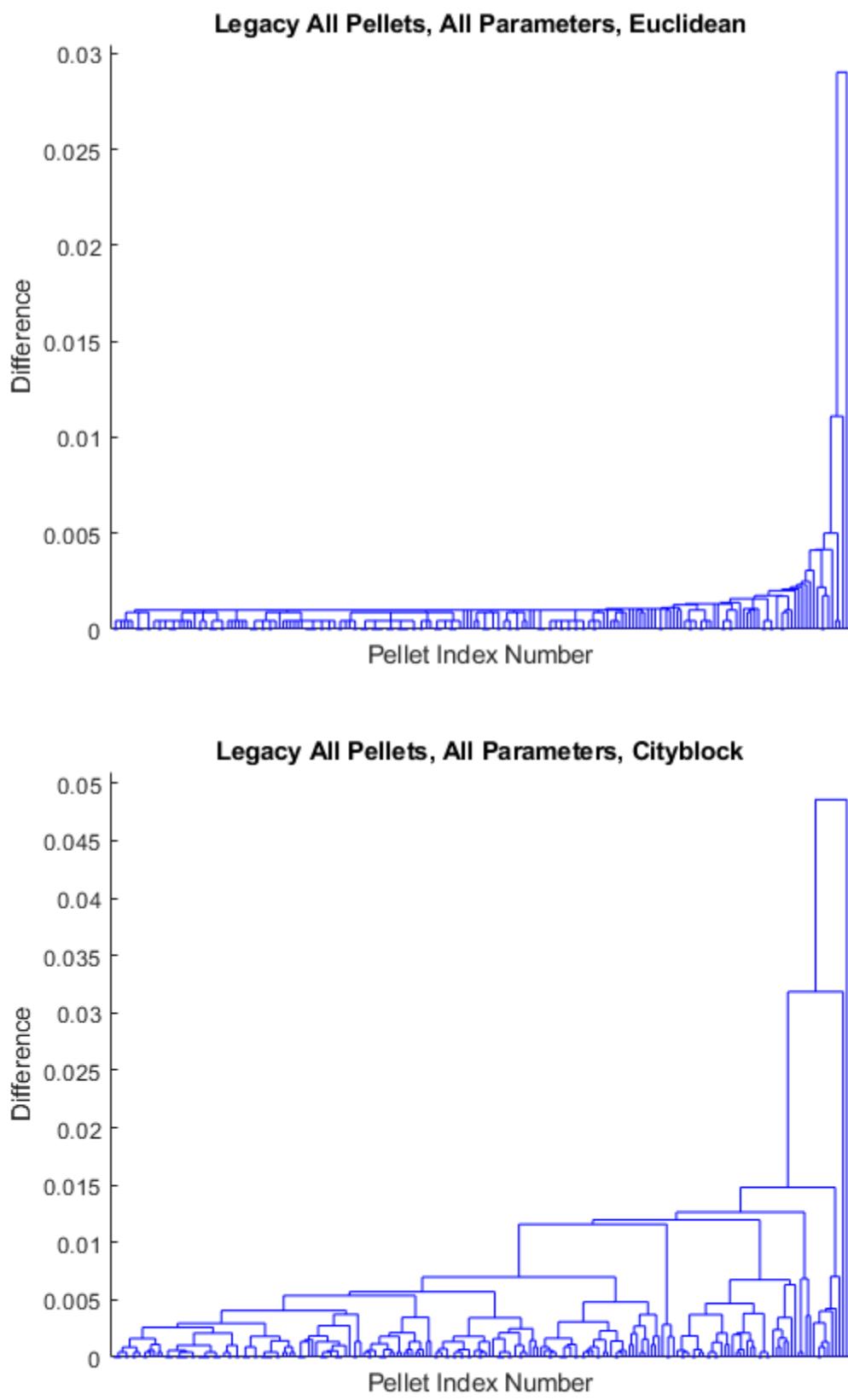












---

# Legacy Data Cophenetic Distances and Inconsistency Coefficients

Euclidean Cophenetic Distances, Height

```
ch1e = cophenet(ztesth1,ytesth1);
ch2e = cophenet(ztesth2,ytesth2);
ch3e = cophenet(ztesth3,ytesth3);
ch4e = cophenet(ztesth4,ytesth4);
chte = cophenet(ztestht,ytestht);
challe = [ch1e ch2e ch3e ch4e chte];
% Cityblock Cophenetic Distances, Height
ch1cb = cophenet(ztesth1cb,ytesth1cb);
ch2cb = cophenet(ztesth2cb,ytesth2cb);
ch3cb = cophenet(ztesth3cb,ytesth3cb);
ch4cb = cophenet(ztesth4cb,ytesth4cb);
chtcb = cophenet(ztesthtcb,ytesthtcb);
challcb = [ch1cb ch2cb ch3cb ch4cb chtcb];
% Maximum Inconsistency Coefficient, using Cityblock, Height
ih1cb = inconsistent(ztesth1cb);
ih1cbmax = max(ih1cb(:,4));
ih2cb = inconsistent(ztesth2cb);
ih2cbmax = max(ih2cb(:,4));
ih3cb = inconsistent(ztesth3cb);
ih3cbmax = max(ih3cb(:,4));
ih4cb = inconsistent(ztesth4cb);
ih4cbmax = max(ih4cb(:,4));
ihtcb = inconsistent(ztesthtcb);
ihtcbmax = max(ihtcb(:,4));
ihmaxallcb = [ih1cbmax ih2cbmax ih3cbmax ih4cbmax ihtcbmax];

% Euclidean Cophenetic Distances, Weight
cw1e = cophenet(ztestw1,ytestw1);
cw2e = cophenet(ztestw2,ytestw2);
cw3e = cophenet(ztestw3,ytestw3);
cw4e = cophenet(ztestw4,ytestw4);
cwte = cophenet(ztestwt,ytestwt);
cwalle = [cw1e cw2e cw3e cw4e cwte];
% Cityblock Cophenetic Distances, Weight
cw1cb = cophenet(ztestw1cb,ytestw1cb);
cw2cb = cophenet(ztestw2cb,ytestw2cb);
cw3cb = cophenet(ztestw3cb,ytestw3cb);
cw4cb = cophenet(ztestw4cb,ytestw4cb);
cwtcb = cophenet(ztestwtcb,ytestwtcb);
cwallcb = [cw1cb cw2cb cw3cb cw4cb cwtcb];
% Maximum Inconsistency Coefficient, using Cityblock, Weight
iw1cb = inconsistent(ztestw1cb);
iw1cbmax = max(iw1cb(:,4));
iw2cb = inconsistent(ztestw2cb);
iw2cbmax = max(iw2cb(:,4));
iw3cb = inconsistent(ztestw3cb);
iw3cbmax = max(iw3cb(:,4));
```

---

```

iw4cb = inconsistent(ztestw4cb);
iw4cbmax = max(iw4cb(:,4));
iwtcb = inconsistent(ztestwtcb);
iwtcbmax = max(iwtcb(:,4));
iwmallcb = [iw1cbmax iw2cbmax iw3cbmax iw4cbmax iwtcbmax];

% Euclidean Cophenetic Distances, Density
cd1e = cophenet(ztestd1,ytestd1);
cd2e = cophenet(ztestd2,ytestd2);
cd3e = cophenet(ztestd3,ytestd3);
cd4e = cophenet(ztestd4,ytestd4);
cdte = cophenet(ztestdt,ytestdt);
cdalle = [cd1e cd2e cd3e cd4e cdte];
% Cityblock Cophenetic Distances, Density
cd1cb = cophenet(ztestd1cb,ytestd1cb);
cd2cb = cophenet(ztestd2cb,ytestd2cb);
cd3cb = cophenet(ztestd3cb,ytestd3cb);
cd4cb = cophenet(ztestd4cb,ytestd4cb);
cdtcb = cophenet(ztestdtcb,ytestdtcb);
cdallcb = [cd1cb cd2cb cd3cb cd4cb cdtcb];
% Maximum Inconsistency Coefficient, using Cityblock, Density
id1cb = inconsistent(ztestd1cb);
id1cbmax = max(id1cb(:,4));
id2cb = inconsistent(ztestd2cb);
id2cbmax = max(id2cb(:,4));
id3cb = inconsistent(ztestd3cb);
id3cbmax = max(id3cb(:,4));
id4cb = inconsistent(ztestd4cb);
id4cbmax = max(id4cb(:,4));
idtcb = inconsistent(ztestdtcb);
idtcbmax = max(idtcb(:,4));
idmaxallcb = [id1cbmax id2cbmax id3cbmax id4cbmax idtcbmax];

% Euclidean Cophenetic Distances, All Parameters
cale = cophenet(ztestall,ytestall); % Tray 1
cale = cophenet(ztestal,ytestal); % All Pellets

% Cityblock Cophenetic Distances, All Parameters
cal1cb = cophenet(ztestallcb,ytestallcb);
calcb = cophenet(ztestalcb,ytestalcb);

% Maximum Inconsistency Coefficient, using Cityblock, All Parameters
iale = inconsistent(ztestall);
ialemax = max(iale(:,4));
ial1cb = inconsistent(ztestallcb);
ial1cbmax = max(ial1cb(:,4));
iale = inconsistent(ztestal);
ialemax = max(iale(:,4));
ialcb = inconsistent(ztestalcb);
ialcbmax = max(ialcb(:,4));

% Tabulate Results (5 is Legacy Population)
copstattable2 = [1 ch1e ch1cb ih1cbmax cw1e cw1cb iw1cbmax cd1e
    cd1cb id1cbmax;2 ch2e ch2cb ih2cbmax cw2e cw2cb iw2cbmax cd2e
    cd2cb id2cbmax;3 ch3e ch3cb ih3cbmax cw3e cw3cb iw3cbmax cd3e
    cd3cb id3cbmax;4 ch4e ch4cb ih4cbmax cw4e cw4cb iw4cbmax cd4e
    cd4cb id4cbmax;5 ch5e ch5cb ih5cbmax cw5e cw5cb iw5cbmax cd5e
    cd5cb id5cbmax;6 ch6e ch6cb ih6cbmax cw6e cw6cb iw6cbmax cd6e
    cd6cb id6cbmax;7 ch7e ch7cb ih7cbmax cw7e cw7cb iw7cbmax cd7e
    cd7cb id7cbmax;8 ch8e ch8cb ih8cbmax cw8e cw8cb iw8cbmax cd8e
    cd8cb id8cbmax;9 ch9e ch9cb ih9cbmax cw9e cw9cb iw9cbmax cd9e
    cd9cb id9cbmax;10 ch10e ch10cb ih10cbmax cw10e cw10cb iw10cbmax cd10e
    cd10cb id10cbmax;11 ch11e ch11cb ih11cbmax cw11e cw11cb iw11cbmax cd11e
    cd11cb id11cbmax;12 ch12e ch12cb ih12cbmax cw12e cw12cb iw12cbmax cd12e
    cd12cb id12cbmax;13 ch13e ch13cb ih13cbmax cw13e cw13cb iw13cbmax cd13e
    cd13cb id13cbmax;14 ch14e ch14cb ih14cbmax cw14e cw14cb iw14cbmax cd14e
    cd14cb id14cbmax;15 ch15e ch15cb ih15cbmax cw15e cw15cb iw15cbmax cd15e
    cd15cb id15cbmax;16 ch16e ch16cb ih16cbmax cw16e cw16cb iw16cbmax cd16e
    cd16cb id16cbmax;17 ch17e ch17cb ih17cbmax cw17e cw17cb iw17cbmax cd17e
    cd17cb id17cbmax;18 ch18e ch18cb ih18cbmax cw18e cw18cb iw18cbmax cd18e
    cd18cb id18cbmax;19 ch19e ch19cb ih19cbmax cw19e cw19cb iw19cbmax cd19e
    cd19cb id19cbmax;20 ch20e ch20cb ih20cbmax cw20e cw20cb iw20cbmax cd20e
    cd20cb id20cbmax;21 ch21e ch21cb ih21cbmax cw21e cw21cb iw21cbmax cd21e
    cd21cb id21cbmax;22 ch22e ch22cb ih22cbmax cw22e cw22cb iw22cbmax cd22e
    cd22cb id22cbmax;23 ch23e ch23cb ih23cbmax cw23e cw23cb iw23cbmax cd23e
    cd23cb id23cbmax;24 ch24e ch24cb ih24cbmax cw24e cw24cb iw24cbmax cd24e
    cd24cb id24cbmax;25 ch25e ch25cb ih25cbmax cw25e cw25cb iw25cbmax cd25e
    cd25cb id25cbmax;26 ch26e ch26cb ih26cbmax cw26e cw26cb iw26cbmax cd26e
    cd26cb id26cbmax;27 ch27e ch27cb ih27cbmax cw27e cw27cb iw27cbmax cd27e
    cd27cb id27cbmax;28 ch28e ch28cb ih28cbmax cw28e cw28cb iw28cbmax cd28e
    cd28cb id28cbmax;29 ch29e ch29cb ih29cbmax cw29e cw29cb iw29cbmax cd29e
    cd29cb id29cbmax;30 ch30e ch30cb ih30cbmax cw30e cw30cb iw30cbmax cd30e
    cd30cb id30cbmax;31 ch31e ch31cb ih31cbmax cw31e cw31cb iw31cbmax cd31e
    cd31cb id31cbmax;32 ch32e ch32cb ih32cbmax cw32e cw32cb iw32cbmax cd32e
    cd32cb id32cbmax;33 ch33e ch33cb ih33cbmax cw33e cw33cb iw33cbmax cd33e
    cd33cb id33cbmax;34 ch34e ch34cb ih34cbmax cw34e cw34cb iw34cbmax cd34e
    cd34cb id34cbmax;35 ch35e ch35cb ih35cbmax cw35e cw35cb iw35cbmax cd35e
    cd35cb id35cbmax;36 ch36e ch36cb ih36cbmax cw36e cw36cb iw36cbmax cd36e
    cd36cb id36cbmax;37 ch37e ch37cb ih37cbmax cw37e cw37cb iw37cbmax cd37e
    cd37cb id37cbmax;38 ch38e ch38cb ih38cbmax cw38e cw38cb iw38cbmax cd38e
    cd38cb id38cbmax;39 ch39e ch39cb ih39cbmax cw39e cw39cb iw39cbmax cd39e
    cd39cb id39cbmax;40 ch40e ch40cb ih40cbmax cw40e cw40cb iw40cbmax cd40e
    cd40cb id40cbmax;41 ch41e ch41cb ih41cbmax cw41e cw41cb iw41cbmax cd41e
    cd41cb id41cbmax;42 ch42e ch42cb ih42cbmax cw42e cw42cb iw42cbmax cd42e
    cd42cb id42cbmax;43 ch43e ch43cb ih43cbmax cw43e cw43cb iw43cbmax cd43e
    cd43cb id43cbmax;44 ch44e ch44cb ih44cbmax cw44e cw44cb iw44cbmax cd44e
    cd44cb id44cbmax;45 ch45e ch45cb ih45cbmax cw45e cw45cb iw45cbmax cd45e
    cd45cb id45cbmax;46 ch46e ch46cb ih46cbmax cw46e cw46cb iw46cbmax cd46e
    cd46cb id46cbmax;47 ch47e ch47cb ih47cbmax cw47e cw47cb iw47cbmax cd47e
    cd47cb id47cbmax;48 ch48e ch48cb ih48cbmax cw48e cw48cb iw48cbmax cd48e
    cd48cb id48cbmax;49 ch49e ch49cb ih49cbmax cw49e cw49cb iw49cbmax cd49e
    cd49cb id49cbmax;50 ch50e ch50cb ih50cbmax cw50e cw50cb iw50cbmax cd50e
    cd50cb id50cbmax;51 ch51e ch51cb ih51cbmax cw51e cw51cb iw51cbmax cd51e
    cd51cb id51cbmax;52 ch52e ch52cb ih52cbmax cw52e cw52cb iw52cbmax cd52e
    cd52cb id52cbmax;53 ch53e ch53cb ih53cbmax cw53e cw53cb iw53cbmax cd53e
    cd53cb id53cbmax;54 ch54e ch54cb ih54cbmax cw54e cw54cb iw54cbmax cd54e
    cd54cb id54cbmax;55 ch55e ch55cb ih55cbmax cw55e cw55cb iw55cbmax cd55e
    cd55cb id55cbmax;56 ch56e ch56cb ih56cbmax cw56e cw56cb iw56cbmax cd56e
    cd56cb id56cbmax;57 ch57e ch57cb ih57cbmax cw57e cw57cb iw57cbmax cd57e
    cd57cb id57cbmax;58 ch58e ch58cb ih58cbmax cw58e cw58cb iw58cbmax cd58e
    cd58cb id58cbmax;59 ch59e ch59cb ih59cbmax cw59e cw59cb iw59cbmax cd59e
    cd59cb id59cbmax;60 ch60e ch60cb ih60cbmax cw60e cw60cb iw60cbmax cd60e
    cd60cb id60cbmax;61 ch61e ch61cb ih61cbmax cw61e cw61cb iw61cbmax cd61e
    cd61cb id61cbmax;62 ch62e ch62cb ih62cbmax cw62e cw62cb iw62cbmax cd62e
    cd62cb id62cbmax;63 ch63e ch63cb ih63cbmax cw63e cw63cb iw63cbmax cd63e
    cd63cb id63cbmax;64 ch64e ch64cb ih64cbmax cw64e cw64cb iw64cbmax cd64e
    cd64cb id64cbmax;65 ch65e ch65cb ih65cbmax cw65e cw65cb iw65cbmax cd65e
    cd65cb id65cbmax;66 ch66e ch66cb ih66cbmax cw66e cw66cb iw66cbmax cd66e
    cd66cb id66cbmax;67 ch67e ch67cb ih67cbmax cw67e cw67cb iw67cbmax cd67e
    cd67cb id67cbmax;68 ch68e ch68cb ih68cbmax cw68e cw68cb iw68cbmax cd68e
    cd68cb id68cbmax;69 ch69e ch69cb ih69cbmax cw69e cw69cb iw69cbmax cd69e
    cd69cb id69cbmax;70 ch70e ch70cb ih70cbmax cw70e cw70cb iw70cbmax cd70e
    cd70cb id70cbmax;71 ch71e ch71cb ih71cbmax cw71e cw71cb iw71cbmax cd71e
    cd71cb id71cbmax;72 ch72e ch72cb ih72cbmax cw72e cw72cb iw72cbmax cd72e
    cd72cb id72cbmax;73 ch73e ch73cb ih73cbmax cw73e cw73cb iw73cbmax cd73e
    cd73cb id73cbmax;74 ch74e ch74cb ih74cbmax cw74e cw74cb iw74cbmax cd74e
    cd74cb id74cbmax;75 ch75e ch75cb ih75cbmax cw75e cw75cb iw75cbmax cd75e
    cd75cb id75cbmax;76 ch76e ch76cb ih76cbmax cw76e cw76cb iw76cbmax cd76e
    cd76cb id76cbmax;77 ch77e ch77cb ih77cbmax cw77e cw77cb iw77cbmax cd77e
    cd77cb id77cbmax;78 ch78e ch78cb ih78cbmax cw78e cw78cb iw78cbmax cd78e
    cd78cb id78cbmax;79 ch79e ch79cb ih79cbmax cw79e cw79cb iw79cbmax cd79e
    cd79cb id79cbmax;80 ch80e ch80cb ih80cbmax cw80e cw80cb iw80cbmax cd80e
    cd80cb id80cbmax;81 ch81e ch81cb ih81cbmax cw81e cw81cb iw81cbmax cd81e
    cd81cb id81cbmax;82 ch82e ch82cb ih82cbmax cw82e cw82cb iw82cbmax cd82e
    cd82cb id82cbmax;83 ch83e ch83cb ih83cbmax cw83e cw83cb iw83cbmax cd83e
    cd83cb id83cbmax;84 ch84e ch84cb ih84cbmax cw84e cw84cb iw84cbmax cd84e
    cd84cb id84cbmax;85 ch85e ch85cb ih85cbmax cw85e cw85cb iw85cbmax cd85e
    cd85cb id85cbmax;86 ch86e ch86cb ih86cbmax cw86e cw86cb iw86cbmax cd86e
    cd86cb id86cbmax;87 ch87e ch87cb ih87cbmax cw87e cw87cb iw87cbmax cd87e
    cd87cb id87cbmax;88 ch88e ch88cb ih88cbmax cw88e cw88cb iw88cbmax cd88e
    cd88cb id88cbmax;89 ch89e ch89cb ih89cbmax cw89e cw89cb iw89cbmax cd89e
    cd89cb id89cbmax;90 ch90e ch90cb ih90cbmax cw90e cw90cb iw90cbmax cd90e
    cd90cb id90cbmax;91 ch91e ch91cb ih91cbmax cw91e cw91cb iw91cbmax cd91e
    cd91cb id91cbmax;92 ch92e ch92cb ih92cbmax cw92e cw92cb iw92cbmax cd92e
    cd92cb id92cbmax;93 ch93e ch93cb ih93cbmax cw93e cw93cb iw93cbmax cd93e
    cd93cb id93cbmax;94 ch94e ch94cb ih94cbmax cw94e cw94cb iw94cbmax cd94e
    cd94cb id94cbmax;95 ch95e ch95cb ih95cbmax cw95e cw95cb iw95cbmax cd95e
    cd95cb id95cbmax;96 ch96e ch96cb ih96cbmax cw96e cw96cb iw96cbmax cd96e
    cd96cb id96cbmax;97 ch97e ch97cb ih97cbmax cw97e cw97cb iw97cbmax cd97e
    cd97cb id97cbmax;98 ch98e ch98cb ih98cbmax cw98e cw98cb iw98cbmax cd98e
    cd98cb id98cbmax;99 ch99e ch99cb ih99cbmax cw99e cw99cb iw99cbmax cd99e
    cd99cb id99cbmax;100 ch100e ch100cb ih100cbmax cw100e cw100cb iw100cbmax cd100e
    cd100cb id100cbmax;

```

---

---

```

cd2cb id2cbmax;3 ch3e ch3cb ih3cbmax cw3e cw3cb iw3cbmax cd3e
cd3cb id3cbmax;4 ch4e ch4cb ih4cbmax cw4e cw4cb iw4cbmax cd4e
cd4cb id4cbmax;5 chte chtcb ihtcbmax cwte cwtcb iwtcbmax cdte cdtcb
idtcbmax];
LegacySortStats = array2table(copstattable2,'VariableNames',
{'Tray','HCDE','HCDCB','HIC','WCDE','WCDCB','WIC','DCDE','DCDCB','DIC'});
copstattable2al = [1 calle callcb iallemax iallcbmax;5 cale calcb
ialemax ialcbmax];
LegacyAllParaStats = array2table(copstattable2al,'VariableNames',
{'Tray','APCDE','APCDCB','APICE','APICCB'})

```

*LegacySortStats* =

5×10 table

Tray	HCDE	HCDCB	HIC	WCDE	WCDCB	WIC
	DCDE	DCDCB	DIC			
1	0.93743	0.94557	1.1547	0.81668	0.79689	
1.1547	0.8436	0.84029	1.1547			
2	0.59532	0.78111	1.1547	0.90152	0.95006	
1.1547	0.88467	0.95036	1.1514			
3	0.54903	0.74655	1.1547	0.73311	0.792	
1.1547	0.81439	0.80456	1.148			
4	0.77063	0.8572	1.1547	0.64288	0.70384	
1.1547	0.67874	0.75449	1.1547			
5	0.87666	0.90168	1.1547	0.75019	0.88367	
1.1547	0.72992	0.8686	1.1547			

*LegacyAllParaStats* =

2×5 table

Tray	APCDE	APCDCB	APICE	APICCB
1	0.76342	0.8799	1.1547	1.1547
5	0.76597	0.87306	1.1547	1.1547

## Legacy Data Machine Clustering

Cluster by Parameter based on 'maxcluster' matching number of trays

```

tray = tray(1:200);
th = cluster(ztesthtcb,'maxclust',4);
LegacyHeightSort = crosstab(th,tray)
cutoff1 = median([ztesthtcb(end-2,3) ztesthtcb(end-1,3)]);
figure('name','Sorted Height Dendrogram')
dendrogram(ztesthtcb,0,'ColorThreshold',cutoff1)

```

---

```

title('Legacy Height, 4 Cluster, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

tw = cluster(ztestwtcb,'maxclust',4);
LegacyWeightSort = crosstab(tw,tray)
cutoff2 = median([ztestwtcb(end-2,3) ztestwtcb(end-1,3)]);
figure('name','Sorted Weight Dendrogram')
dendrogram(ztestwtcb,0,'ColorThreshold',cutoff2)
title('Legacy Weight, 4 Cluster, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

td = cluster(ztestdtcb,'maxclust',4);
LegacyDensitySort = crosstab(td,tray)
cutoff3 = median([ztestdtcb(end-2,3) ztestdtcb(end-1,3)]);
figure('name','Sorted Density Dendrogram')
dendrogram(ztestdtcb,0,'ColorThreshold',cutoff3)
title('Legacy Density, 4 Cluster, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

% Plot Legacy All Pellet All Parameter by i for report
tali = cluster(ztestalcb,'cutoff',1.115);
LegacyAllParaSorti = crosstab(tali,tray)
cutoffali = mean(ztestalcb(end-10,3));
figure('name','Sorted All Parameter Dendrogram, by i')
dendrogram(ztestalcb,0,'ColorThreshold',cutoffali)
title('Legacy All Parameter, 4 Cluster, Cityblock, sorted to i')
xlabel('Pellet Index Number')
ylabel('Difference (unitless)')
set(gca,'xtick',[])

% Plot Legacy All Pellet All Parameter Max Cluster
tal = cluster(ztestalcb,'maxclust',4);
LegacyAllParaSort = crosstab(tal,tray)
cutoffal = ztestalcb(end-3,3);
figure('name','Sorted All Parameter Dendrogram')
dendrogram(ztestalcb,0,'ColorThreshold',cutoffal)
title('Legacy All Parameter, 4 Cluster, Cityblock')
xlabel('Pellet Index Number')
ylabel('Difference (unitless)')
set(gca,'xtick',[])

% Display Clustered Results
figure('name','Legacy Height vs. Weight vs. Density, All Pellets, 4
Cluster')
map = [1 0 0; 0.25 0.75 0.25; 0 0 1; 0.75 0 0.75];
colormap(map)
scatter3(hl,wl,dl,10,tal,'filled')
xlabel('Height (mm)')

```

---

---

```
ylabel('Weight (g)')
zlabel('Density (g/cc)')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
title('Legacy Measurements, 4 Cluster, Cityblock')
grid on
```

*LegacyHeightSort* =

0	0	1	0
4	0	0	0
43	50	49	50
3	0	0	0

*LegacyWeightSort* =

8	1	3	0
40	43	46	50
2	5	1	0
0	1	0	0

*LegacyDensitySort* =

1	0	0	0
5	11	5	12
44	38	45	38
0	1	0	0

*LegacyAllParaSorti* =

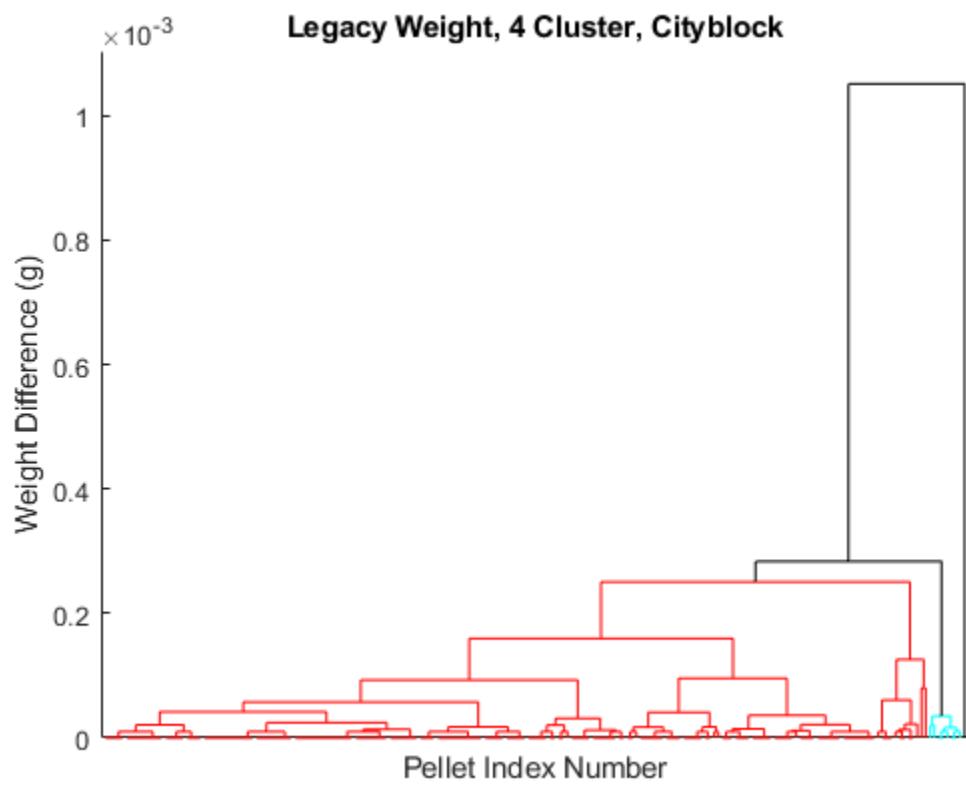
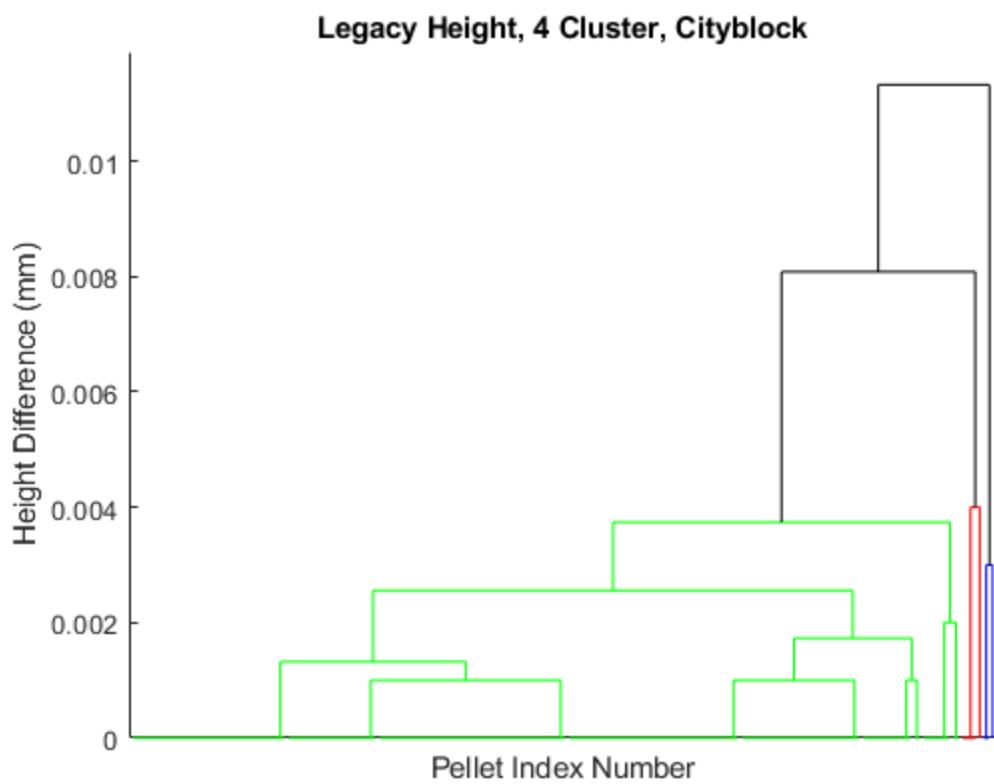
0	1	1	0
0	1	1	0
1	0	0	1
0	1	1	0
1	0	3	0
0	0	0	2
3	0	0	1
1	1	0	0
2	1	0	0
0	0	0	2
2	0	0	1
1	0	0	1
1	0	1	0
1	1	0	0
1	3	0	0
1	0	0	0
0	1	2	0
1	0	0	0
0	0	2	0

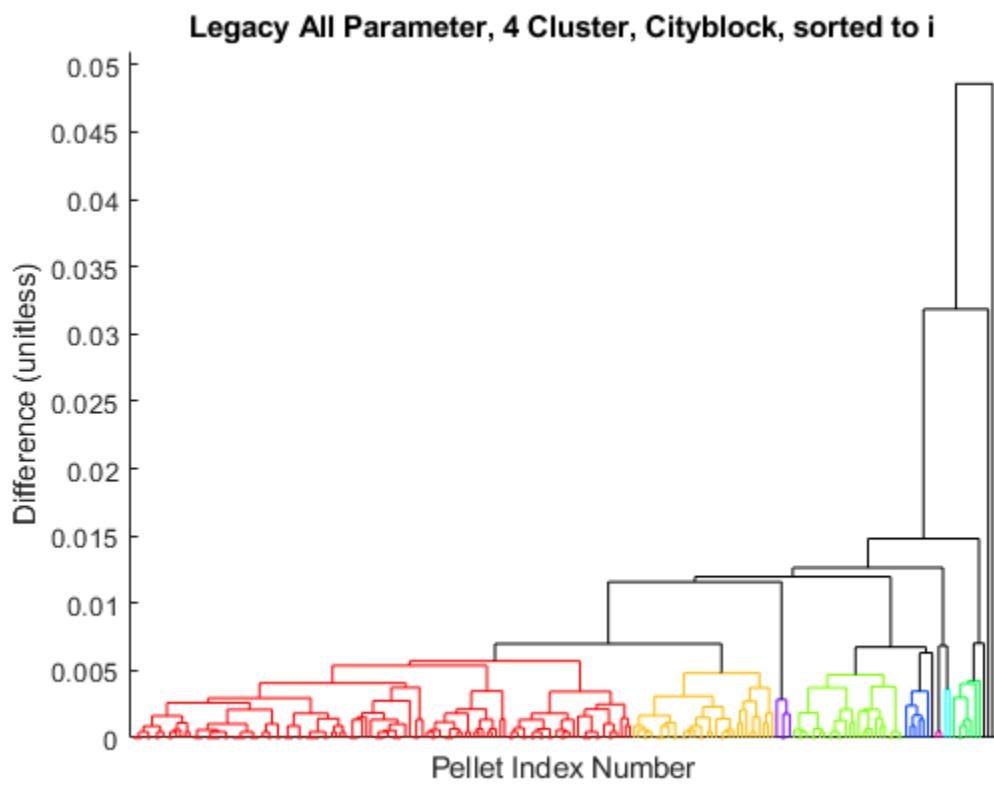
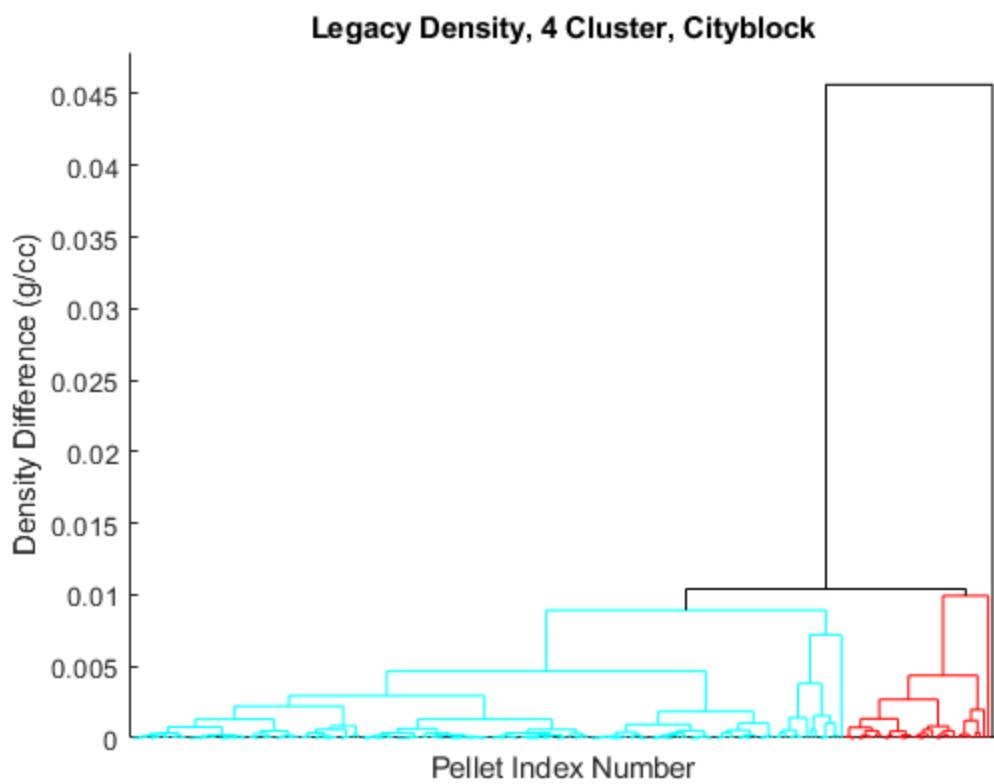
---

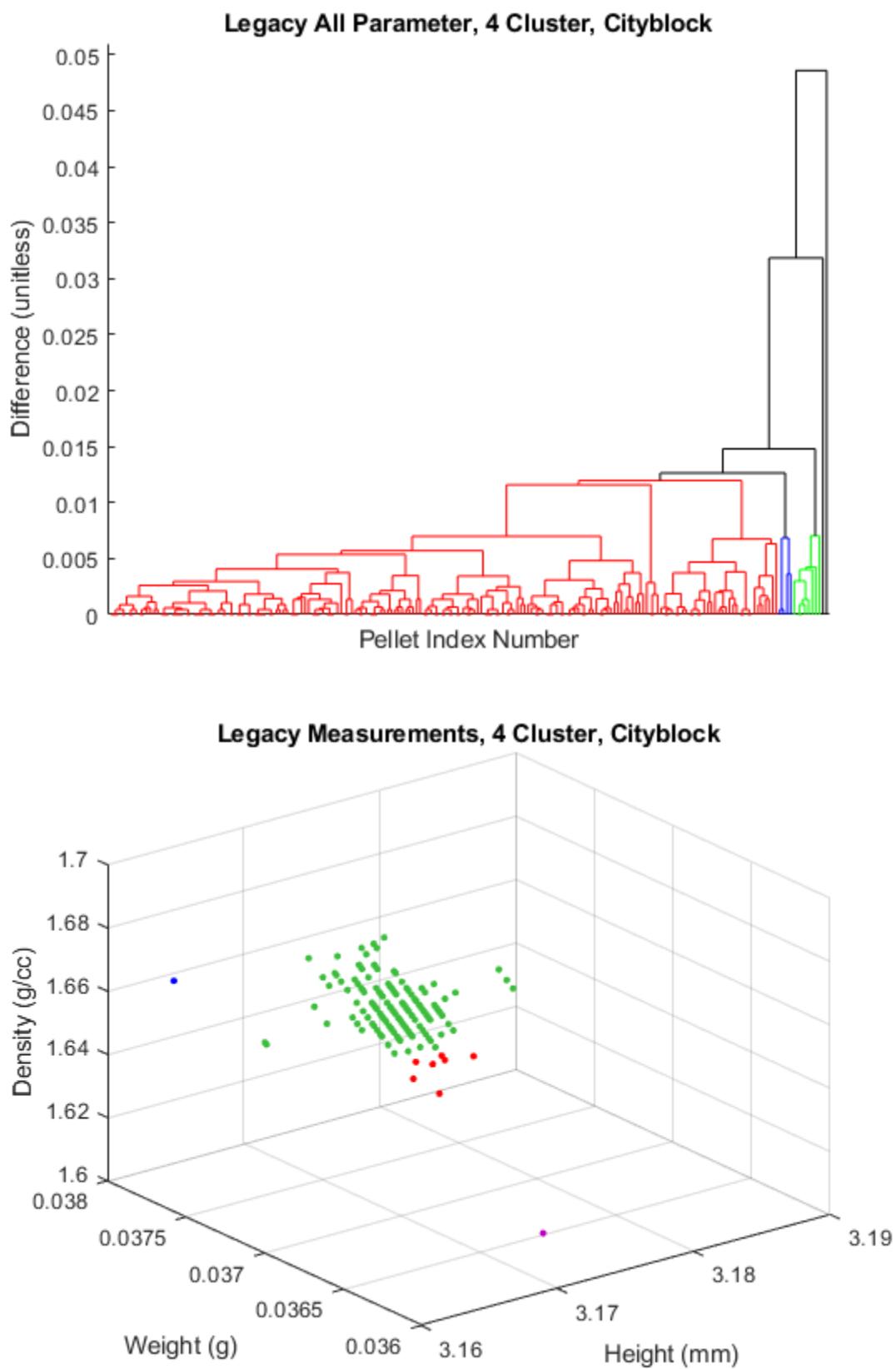
1	1	1	1
0	0	1	1
0	1	2	1
1	1	3	0
0	2	1	0
3	1	6	1
0	0	2	0
4	0	0	0
2	0	0	2
7	0	1	0
1	0	0	0
0	1	0	0
0	1	1	1
0	1	0	1
0	1	0	1
2	0	1	0
0	2	0	0
0	1	1	2
2	1	0	0
0	0	0	2
1	1	0	1
0	1	0	1
1	0	1	2
1	1	3	0
0	1	2	0
1	1	2	1
0	2	1	2
1	0	1	2
1	1	1	2
1	4	1	2
0	2	0	5
2	3	2	11
1	4	4	0
1	5	1	0

*LegacyAllParaSort* =

7	0	1	0
42	49	49	50
1	0	0	0
0	1	0	0







---

# Updated Data Import

```
% Updated Outer Diameter
odu = xlsread('updated_od.xlsx');
odlu = [od(:,1); od(:,2); od(:,3); od(:,4); odu(:,1)];
% Updated Height
hu = xlsread('updated_height.xlsx');
hlu = [h(:,1); h(:,2); h(:,3); h(:,4); hu(:,1)];
% Updated Weight
wu = xlsread('updated_weight.xlsx');
wlu = [w(:,1); w(:,2); w(:,3); w(:,4); wu(:,1)];
% Updated Density
du = xlsread('updated_density.xlsx');
dlu = [d(:,1); d(:,2); d(:,3); d(:,4); du(:,1)];
% Updated All Parameters (ODxHxWxD for Legacy + Updated Tray 1)
alu = xlsread('updated_all.xlsx');
% Tray Index Assignment for Clustering (add to original index)
tray(201:250) = {'Tray 1 - Updated'};
```

# Updated Data Plotting

```
% Plot Legacy Outer Diameter (Compare to Legacy Tray 1 Data)
figure('name','Updated Measurement Data and Legacy Data, Tray 1')
ax2 = subplot(2,2,1);
scatter(p,od(:,1),'filled')
xlim([1 50])
ylim([2.9 3.1])
hold on
scatter(p,odu(:,1),'g','filled')
legend(ax2,'Legacy Tray 1','Updated Tray
1','location','southoutside','orientation','horizontal')
title('Updated Outer Diameter and Legacy Outer Diameter, Tray 1')
xlabel('Pellet Index Number')
ylabel('Pellet Diameter (mm)')
grid on

% Plot Updated Height
subplot(2,2,2)
scatter(p,h(:,1),'filled')
hold on
scatter(p,hu(:,1),'g','filled')
xlim([1 50])
ylim([3.16 3.19])
% legend('Updated Tray 1','Legacy Tray
1','location','northeastoutside')
title('Updated Height and Legacy Height, Tray 1')
xlabel('Pellet Index Number')
ylabel('Pellet Height (mm)')
grid on

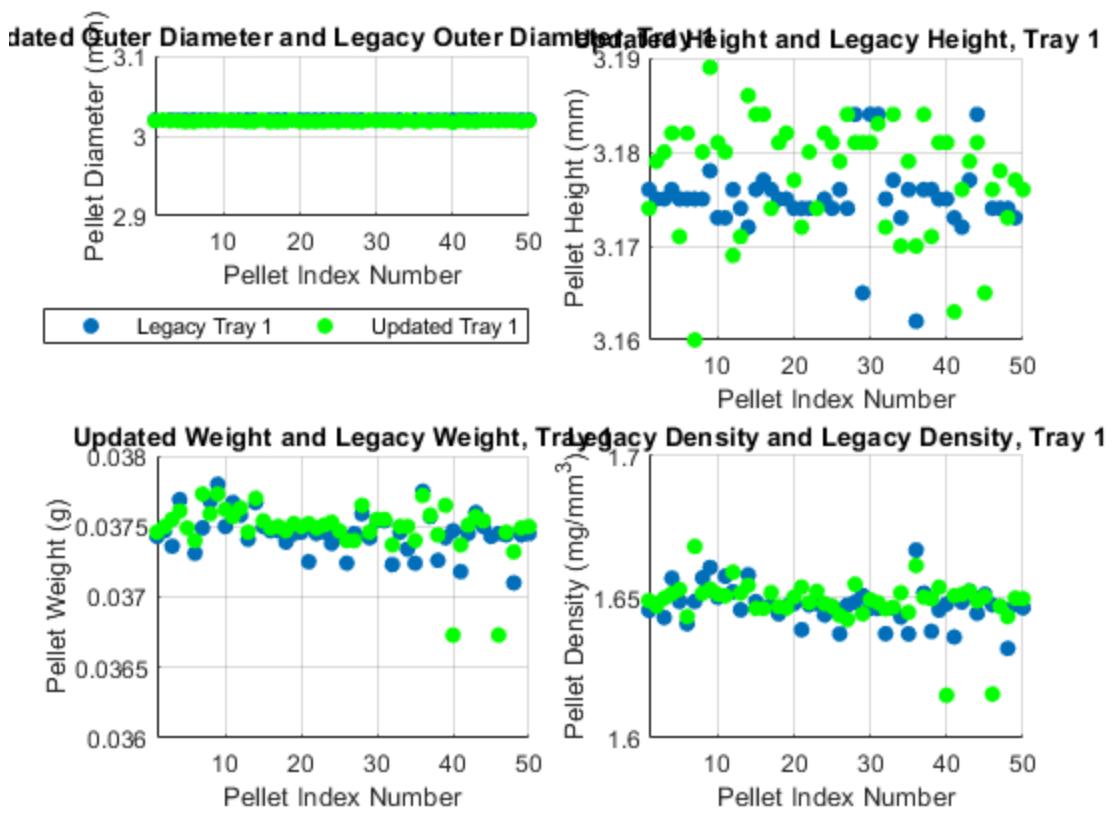
% Plot Updated Weight
subplot(2,2,3)
```

```

scatter(p,w(:,1), 'filled')
hold on
scatter(p,wu(:,1), 'g', 'filled')
xlim([1 50])
ylim([0.0360 0.0380])
%legend('Updated Tray 1','Legacy Tray
1','location','northeastoutside')
title('Updated Weight and Legacy Weight, Tray 1')
xlabel('Pellet Index Number')
ylabel('Pellet Weight (g)')
grid on

% Plot Legacy Density
subplot(2,2,4)
scatter(p,d(:,1), 'filled')
hold on
scatter(p,du(:,1), 'g', 'filled')
xlim([1 50])
ylim([1.6 1.7])
%legend('Updated Tray 1','Legacy Tray
1','location','northeastoutside')
title('Legacy Density and Legacy Density, Tray 1')
xlabel('Pellet Index Number')
ylabel('Pellet Density (mg/mm^{3})')
grid on

```



---

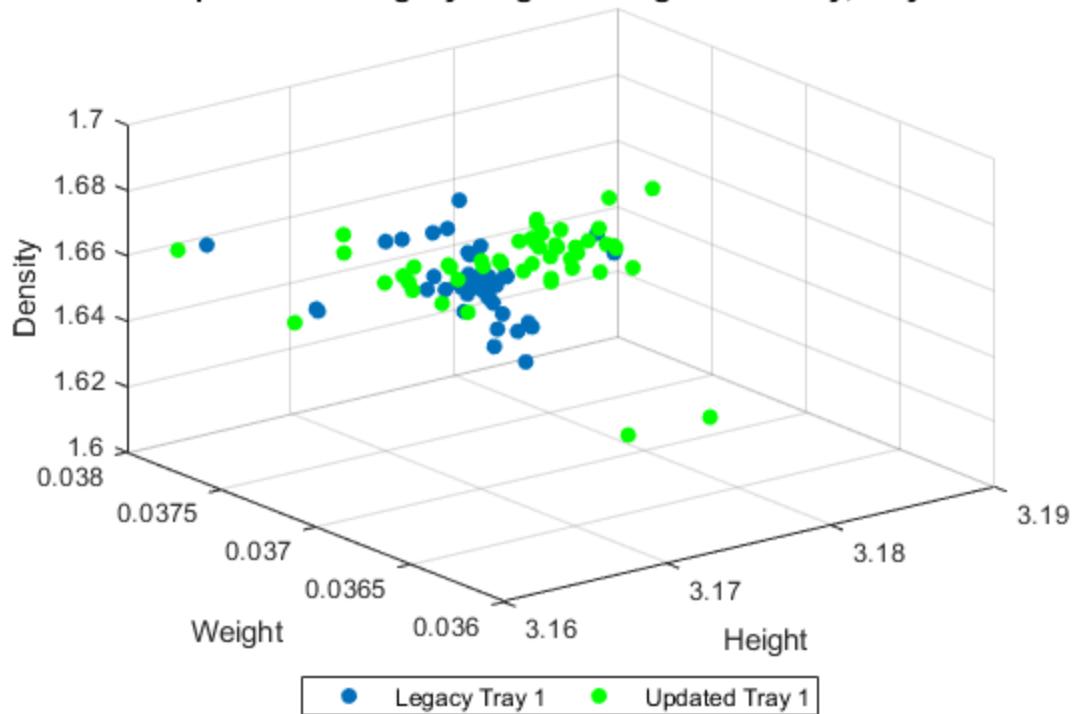
# Updated Data 3D Scatter Plot

Updated data from Tray 1 compared to legacy data

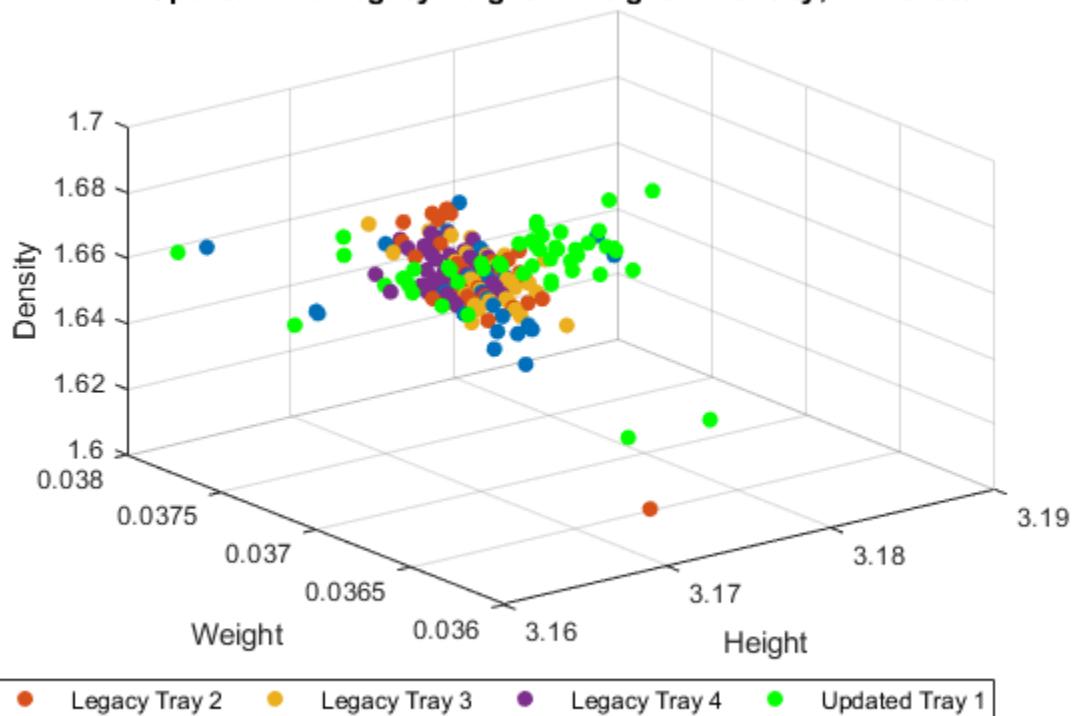
```
figure('name','Updated and Legacy Height v. Weight v. Density, Tray
1')
scatter3(h(:,1),w(:,1),d(:,1),'filled')
hold on
scatter3(hu(:,1),wu(:,1),du(:,1),'g','filled')
title('Updated and Legacy Height v. Weight v. Density, Tray 1')
xlabel('Height')
ylabel('Weight')
zlabel('Density')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
legend('Legacy Tray 1','Updated Tray
1','location','southoutside','orientation','horizontal')
grid on

figure('name','Updated and Legacy Height v. Weight v. Density, All
Pellets')
scatter3(x(:,1),y(:,1),z(:,1),'filled')
hold on
scatter3(x(:,2),y(:,2),z(:,2),'filled')
scatter3(x(:,3),y(:,3),z(:,3),'filled')
scatter3(x(:,4),y(:,4),z(:,4),'filled')
scatter3(hu(:,1),wu(:,1),du(:,1),'g','filled')
title('Updated and Legacy Height v. Weight v. Density, All Pellets')
xlabel('Height')
ylabel('Weight')
zlabel('Density')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
legend('Legacy Tray 1','Legacy Tray 2','Legacy
Tray 3','Legacy Tray 4','Updated Tray
1','location','southoutside','orientation','horizontal')
```

**Updated and Legacy Height v. Weight v. Density, Tray 1**



**Updated and Legacy Height v. Weight v. Density, All Pellets**



---

# Updated Data Statistics

For Updated Outer Diameter

```
odmeanu = mean(odu);
odstdu = std(odu);
odmodeu = mode(odu);
odmedianu = median(odu);
odminu = min(odu);
odmaxu = max(odu);

% For Updated Height
hmeanu = mean(hu);
hstdu = std(hu);
hmodeu = mode(hu);
hmedianu = median(hu);
hminu = min(hu);
hmaxu = max(hu);

% For Updated Weight
wmeanu = mean(wu);
wstdu = std(wu);
wmodeu = mode(wu);
wmedianu = median(wu);
wminu = min(wu);
wmaxu = max(wu);

% For Updated Density
dmeanu = mean(du);
dstdu = std(du);
dmodeu = mode(du);
dmedianu = median(du);
dminu = min(du);
dmaxu = max(du);

% For Updated Total Populations (Legacy Tray 1-4 + Updated Tray 1)
odlmeanu = mean(odlu);
hlmeanu = mean(hlu);
wlmeanu = mean(wlu);
dlmeanu = mean(dlu);
odlstdu = std(odlu);
hlstdu = std(hlu);
wlstdu = std(wlu);
dlstdu = std(dlu);
odlmodeu = mode(odlu);
hlmodeu = mode(hlu);
wlmodeu = mode(wlu);
dlmodeu = mode(dlu);
odlmedianu = median(odlu);
hlmedianu = median(hlu);
wlmedianu = median(wlu);
dlmedianu = median(dlu);
odlminu = min(odlu);
```

---

```

hlminu = min(hlu);
wlminu = min(wlu);
dlminu = min(dlu);
odlmaxu = max(odlu);
hlmaxu = max(hlu);
wlmaxu = max(wlu);
dlmaxu = max(dlu);

% Organize Updated Statistical Data for Tray 1
tstattablelu = [{ 'Mean' } odmeanu(1) hmeanu(1) wmeanu(1) dmeanu(1);
{ 'STD' } odstdu(1) hstdu(1) wstdu(1) dstdu(1); { 'Mode' } odmodeu(1)
hmodeu(1) wmodeu(1) dmodeu(1); { 'Median' } odmedianu(1) hmedianu(1)
wmedianu(1) dmedianu(1); { 'Min' } odminu(1) hminu(1) wminu(1) dminu(1);
{ 'Max' } odmaxu(1) hmaxu(1) wmaxu(1) dmaxu(1);

% Display in table
UpdatedTray1Stats = cell2table(tstattablelu, 'VariableNames',
{ 'Parameter', 'OD_mm', 'H_mm', 'W_g', 'D_g_per_cc' })

% Organize Updated Data by Parameter (6 is Updated Tray 1, 7 is
% Updated Population)
gstattablelu = [6 odmeanu(1) odstdu(1) odmodeu(1) odmedianu(1)
odminu(1) odmaxu(1); 7 odlmeanu(1) odlstdu(1) odlmodeu(1)
odlmedianu(1) odlminu(1) odlmaxu(1)];
gstattable2u = [6 hmeanu(1) hstdu(1) hmodeu(1) hmedianu(1) hminu(1)
hmaxu(1); 7 hlmeanu(1) hlstdu(1) hlmodeu(1) hlmedianu(1) hlminu(1)
hlmaxu(1)];
gstattable3u = [6 wmeanu(1) wstdu(1) wmodeu(1) wmedianu(1) wminu(1)
wmaxu(1); 7 wlmeanu(1) wlstdu(1) wlmodeu(1) wlmedianu(1) wlminu(1)
wlmaxu(1)];
gstattable4u = [6 dmeanu(1) dstdu(1) dmodeu(1) dmedianu(1) dminu(1)
dmaxu(1); 7 dlmeanu(1) dlstdu(1) dlmodeu(1) dlmedianu(1) dlminu(1)
dlmaxu(1)];

% Display in tables
UpdatedODStats = array2table(gstattablelu, 'VariableNames',
{ 'Tray', 'ODMn_mm', 'ODSTD_mm', 'ODMd_mm', 'ODMed_mm', 'ODMin_mm', 'ODMax_mm' });
UpdatedHStats = array2table(gstattable2u, 'VariableNames',
{ 'Tray', 'HMn_mm', 'HSTD_mm', 'HMd_mm', 'HMed_mm', 'HMin_mm', 'HMax_mm' });
UpdatedWStats = array2table(gstattable3u, 'VariableNames',
{ 'Tray', 'WMn_g', 'WSTD_g', 'WMd_g', 'WMed_g', 'WMin_g', 'WMax_g' });
UpdatedDStats = array2table(gstattable4u, 'VariableNames',
{ 'Tray', 'DMn_g_per_cc', 'DSTD_g_per_cc', 'DMd_g_per_cc', 'DMed_g_per_cc', 'DMin_g_per_cc' });

% Updated Total Population Values, Tabulated
pstattablelu = [{ 'Mean' } odlmeanu hlmeanu wlmeanu dlmeanu; { 'STD' }
odlstdu hlstdu wlstdu dlstdu; { 'Mode' } odlmodeu hlmodeu wlmodeu
dlmodeu; { 'Median' } odlmedianu hlmedianu wlmedianu dlmedianu; { 'Min' }
odlminu hlminu wlminu dlminu; { 'Max' } odlmaxu hlmaxu wlmaxu dlmaxu];
UpdatedPopStats = cell2table(pstattablelu, 'VariableNames',
{ 'Parameter', 'OD_mm', 'H_mm', 'W_g', 'D_g_per_cc' })

UpdatedTray1Stats =

```

---

---

6x5 table

Parameter	OD_mm	H_mm	W_g	D_g_per_cc
'Mean'	3.0187	3.1776	0.037434	1.6484
'STD'	0.0007354	0.0060271	0.00043301	0.0082048
'Mode'	3.019	3.181	0.0375	1.6466
'Median'	3.019	3.1795	0.0375	1.6495
'Min'	3.017	3.16	0.03471	1.6152
'Max'	3.02	3.189	0.03773	1.6679

UpdatedODStats =

2x7 table

Tray	ODMn_mm	ODSTD_mm	ODMd_mm	ODMed_mm	ODMin_mm
ODMax_mm					
6	3.0187	0.0007354	3.019	3.019	3.017
3.02					
7	3.0197	0.00061475	3.02	3.02	3.017
3.02					

UpdatedHStats =

2x7 table

Tray	HMn_mm	HSTD_mm	HMd_mm	HMed_mm	HMin_mm
HMax_mm					
6	3.1776	0.0060271	3.181	3.1795	3.16
3.189					
7	3.1756	0.0036213	3.174	3.175	3.16
3.189					

UpdatedWStats =

2x7 table

Tray	WMn_g	WSTD_g	WMd_g	WMed_g	WMin_g
WMax_g					
6	0.037434	0.00043301	0.03471	0.03773	0.03773
3.02					
7	0.0375	0.00061475	0.0375	0.0375	0.0375
3.02					

---

6	0.037434	0.00043301	0.0375	0.0375	0.03471
0.03773					
7	0.037476	0.00023015	0.0375	0.03748	0.03471
0.0378					

*UpdatedDStats =*

2x7 table

	<i>Tray</i>	<i>DMn_g_per_cc</i>	<i>DSTD_g_per_cc</i>	<i>DMd_g_per_cc</i>	<i>DMed_g_per_cc</i>	<i>DMin_g_per_cc</i>	<i>DMax_g_per_cc</i>
6	1.6484	0.0082048	1.6466	1.6495	1.6152	1.6679	
7	1.6482	0.0066434	1.6467	1.6481	1.6028	1.6679	

*UpdatedPopStats =*

6x5 table

<i>Parameter</i>	<i>OD_mm</i>	<i>H_mm</i>	<i>W_g</i>	<i>D_g_per_cc</i>
'Mean'	3.0197	3.1756	0.037476	1.6482
'STD'	0.00061475	0.0036213	0.00023015	0.0066434
'Mode'	3.02	3.174	0.0375	1.6467
'Median'	3.02	3.175	0.03748	1.6481
'Min'	3.017	3.16	0.03471	1.6028
'Max'	3.02	3.189	0.0378	1.6679

## Updated Data Histograms

Compare to Legacy Data Updated Height, default bins (10)

```
figure('name','Updated Height Histograms, Tray 1, 10 Bins')
subplot(1,2,1)
histfit(hu(:,1))
title('Updated Height, Tray 1, 10 Bins')
xlabel('Height (mm)')
xlim([3.15 3.20])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(1,2,2)
histfit(h(:,1)) % Legacy
title('Legacy Height, Tray 1, 10 Bins')
xlabel('Height (mm)')
```

---

```
    xlim([3.15 3.20])
    ylabel('# of Pellets')
    ylim([0 25])
    grid on

    % Updated Height, 2x bins (20)
    figure('name','Updated Height Histograms, Tray 1, 20 Bins')
    subplot(1,2,1)
    histfit(hu(:,1),20)
    title('Updated Height, Tray 1, 20 Bins')
    xlabel('Height (mm)')
    xlim([3.15 3.20])
    ylabel('# of Pellets')
    ylim([0 25])
    grid on
    subplot(1,2,2)
    histfit(h(:,1),20)
    title('Legacy Height, Tray 1, 20 Bins')
    xlabel('Height (mm)')
    xlim([3.15 3.20])
    ylabel('# of Pellets')
    ylim([0 25])
    grid on

    % Updated Weight, default bins (10)
    figure('name','Updated Weight Histograms, Tray 1, 10 Bins')
    subplot(1,2,1)
    histfit(wu(:,1))
    title('Updated Weight, Tray 1, 10 Bins')
    xlabel('Weight (g)')
    xlim([0.0360 0.0390])
    ylabel('# of Pellets')
    ylim([0 50])
    grid on
    subplot(1,2,2)
    histfit(w(:,1))
    title('Legacy Weight, Tray 1, 10 Bins')
    xlabel('Weight (g)')
    xlim([0.0360 0.0390])
    ylabel('# of Pellets')
    ylim([0 50])
    grid on

    % Updated Weight, 2x bins (20)
    figure('name','Updated Weight Histograms, Tray 1, 20 Bins')
    subplot(1,2,1)
    histfit(wu(:,1),20)
    title('Updated Weight, Tray 1, 20 Bins')
    xlabel('Weight (g)')
    xlim([0.0360 0.0390])
    ylabel('# of Pellets')
    ylim([0 50])
    grid on
    subplot(1,2,2)
```

---

```

histfit(w(:,1),20)
title('Legacy Weight, Tray 1, 20 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0390])
ylabel('# of Pellets')
ylim([0 50])
grid on

% Updated Density, default bins (10)
figure('name','Updated Density Histograms, Tray 1, 10 Bins')
subplot(1,2,1)
histfit(du(:,1))
title('Updated Density, Tray 1, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.60 1.68])
ylabel('# of Pellets')
ylim([0 30])
grid on
subplot(1,2,2)
histfit(d(:,1))
title('Legacy Density, Tray 1, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.60 1.68])
ylabel('# of Pellets')
ylim([0 30])
grid on

% Updated Density, 2x bins (20)
figure('name','Updated Density Histograms, Tray 1, 20 Bins')
subplot(1,2,1)
histfit(du(:,1),20)
title('Updated Density, Tray 1, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.60 1.68])
ylabel('# of Pellets')
ylim([0 30])
grid on
subplot(1,2,2)
histfit(d(:,1),20)
title('Legacy Density, Tray 1, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.60 1.68])
ylabel('# of Pellets')
ylim([0 30])
grid on

% Updated Total Population Values, default bins (10)
% Compared to Legacy
figure('name','Updated Total Population Histograms, 10 Bins')
subplot(3,2,1)
histfit(hlu)
title('Updated Total Population, Height, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])

```

---

---

```

ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,2,3)
histfit(wlu)
title('Updated Total Population, Weight, 10 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0385])
ylabel('# of Pellets')
ylim([0 150])
grid on
subplot(3,2,5)
histfit(dlu)
title('Updated Total Population, Density, 10 Bins')
xlabel('Density (g/cc)')
ylabel('# of Pellets')
xlim([1.6 1.68])
ylim([0 100])
grid on
subplot(3,2,2)
histfit(hl)
title('Legacy Total Population, Height, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,2,4)
histfit(wl)
title('Legacy Total Population, Weight, 10 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0385])
ylabel('# of Pellets')
ylim([0 150])
grid on
subplot(3,2,6)
histfit(dl)
title('Legacy Total Population, Density, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.6 1.68])
ylabel('# of Pellets')
ylim([0 100])
grid on

% Updated Total Population Values, 2x bins (20)
% Compare to Legacy
figure('name','Updated Total Population Histograms, 20 Bins')
subplot(3,2,1)
histfit(hlu,20)
title('Updated Total Population, Height, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 100])

```

---

---

```

grid on
subplot(3,2,3)
histfit(wlu,20)
title('Updated Total Population, Weight, 20 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0385])
ylabel('# of Pellets')
ylim([0 150])
grid on
subplot(3,2,5)
histfit(dlu,20)
title('Updated Total Population, Density, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.6 1.68])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,2,2)
histfit(hl,20)
title('Legacy Total Population, Height, 20 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,2,4)
histfit(wl,20)
title('Legacy Total Population Weight, 20 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0385])
ylabel('# of Pellets')
ylim([0 150])
grid on
subplot(3,2,6)
histfit(dl,20)
title('Legacy Total Population Density, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.6 1.68])
ylabel('# of Pellets')
ylim([0 100])
grid on

% Re-plot Tray 1 Parameters in one figure for report
figure('name','Updated Tray 1 Histograms, 10 & 20 Bins')
subplot(3,2,1)
histfit(hu(:,1))
title('Updated Height, Tray 1, 10 Bins')
xlabel('Height (mm)')
xlim([3.15 3.20])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(3,2,3)

```

---

---

```

histfit(wu(:,1))
title('Updated Weight, Tray 1, 10 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0390])
ylabel('# of Pellets')
ylim([0 50])
grid on
subplot(3,2,1)
histfit(du(:,1))
title('Updated Density, Tray 1, 10 Bins')
xlabel('Density (g/cc)')
xlim([1.60 1.68])
ylabel('# of Pellets')
ylim([0 30])
grid on
subplot(3,2,2)
histfit(hu(:,1),20)
title('Updated Height, Tray 1, 20 Bins')
xlabel('Height (mm)')
xlim([3.15 3.20])
ylabel('# of Pellets')
ylim([0 25])
grid on
subplot(3,2,4)
histfit(wu(:,1),20)
title('Updated Weight, Tray 1, 20 Bins')
xlabel('Weight (g)')
xlim([0.0360 0.0390])
ylabel('# of Pellets')
ylim([0 50])
grid on
subplot(3,2,6)
histfit(du(:,1),20)
title('Updated Density, Tray 1, 20 Bins')
xlabel('Density (g/cc)')
xlim([1.60 1.68])
ylabel('# of Pellets')
ylim([0 30])
grid on

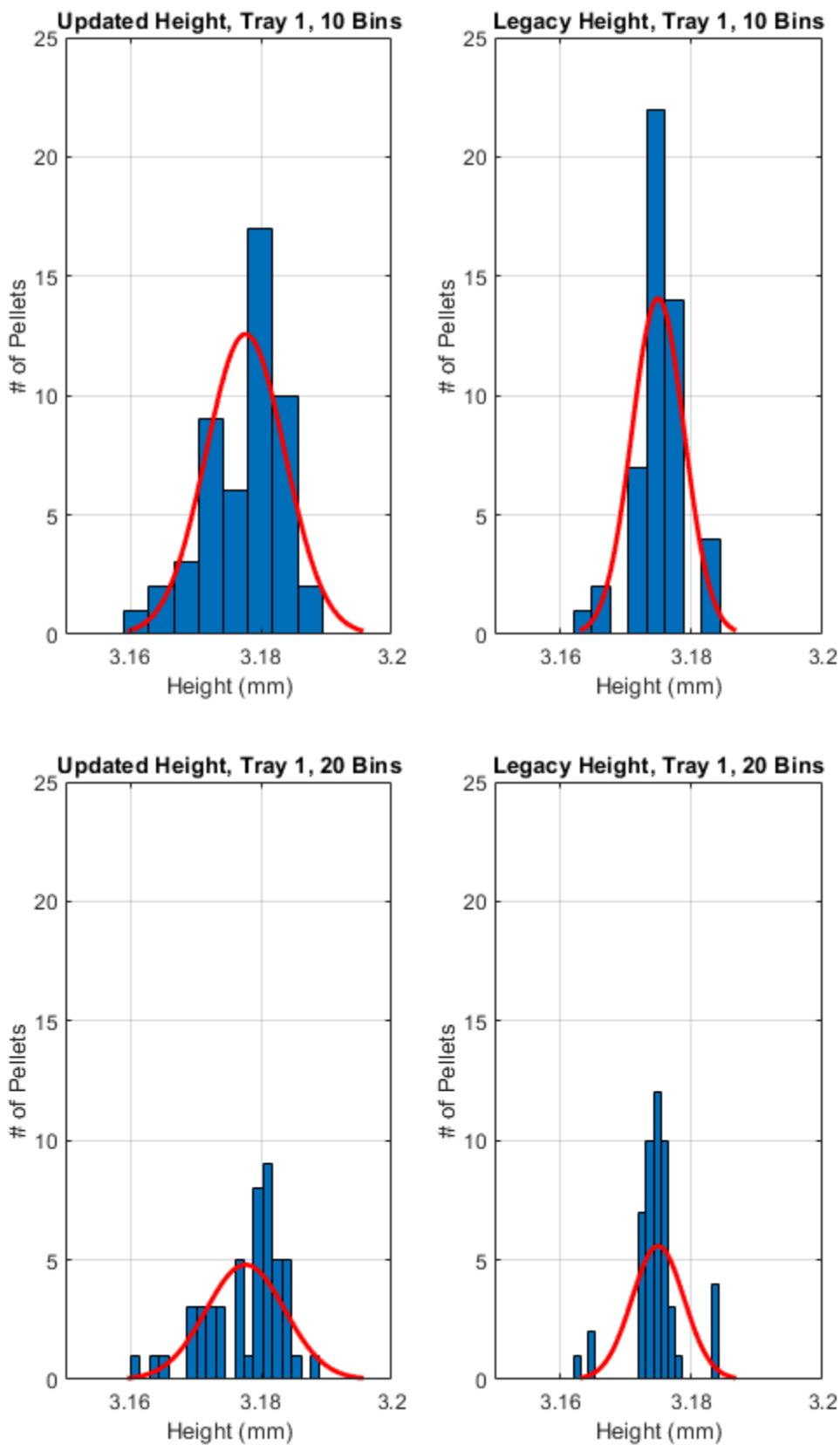
% Total Population 10 & 20 Bin Figure for report
figure('name','Updated Total Polulation Histograms, 10 & 20 Bins')
subplot(3,2,1)
histfit(hlu)
title('Updated Total Polulation, Height, 10 Bins')
xlabel('Height (mm)')
xlim([3.16 3.19])
ylabel('# of Pellets')
ylim([0 100])
grid on
subplot(3,2,3)
histfit(wlu)
title('Updated Total Polulation, Weight, 10 Bins')
xlabel('Weight (g)')

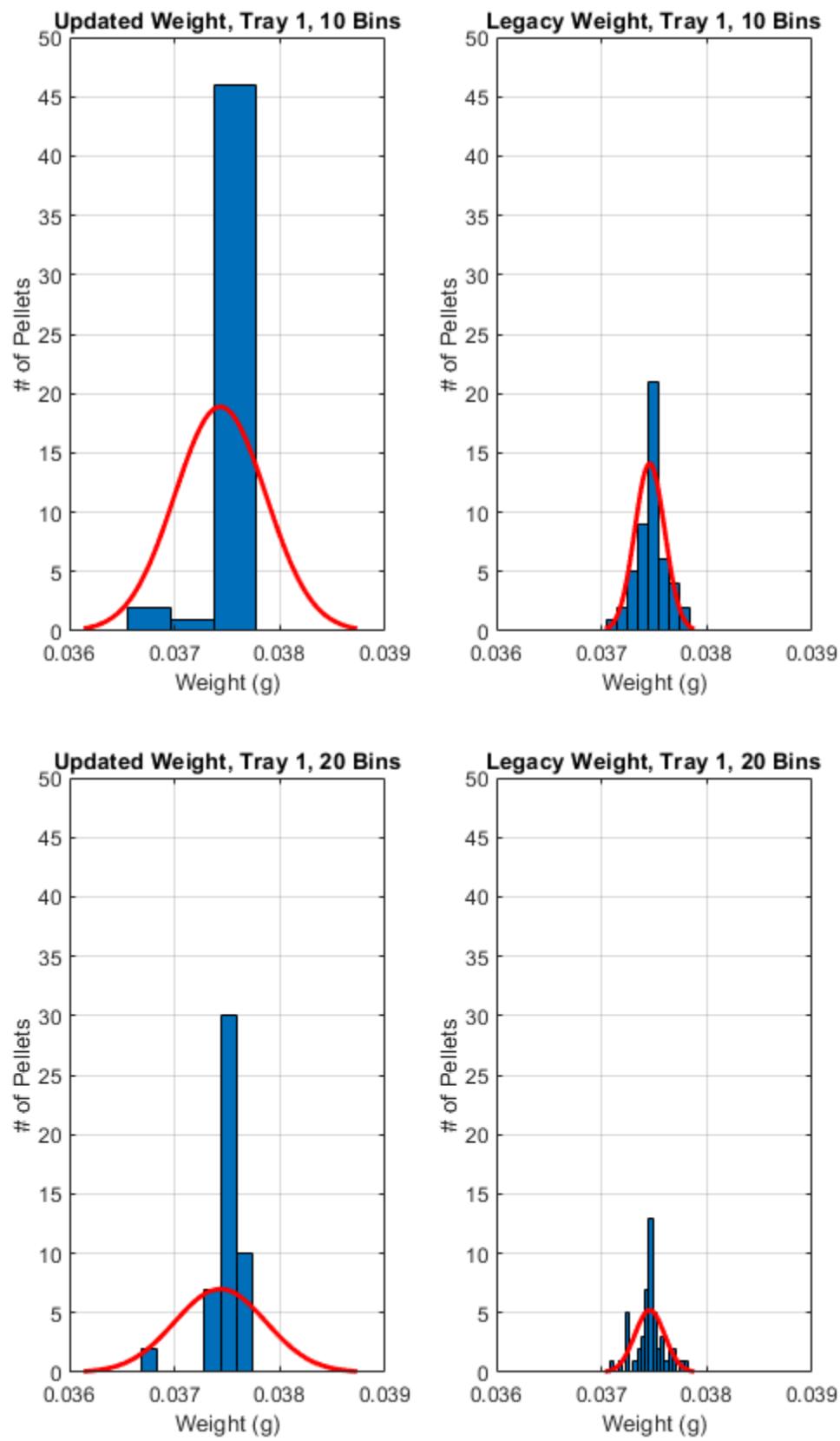
```

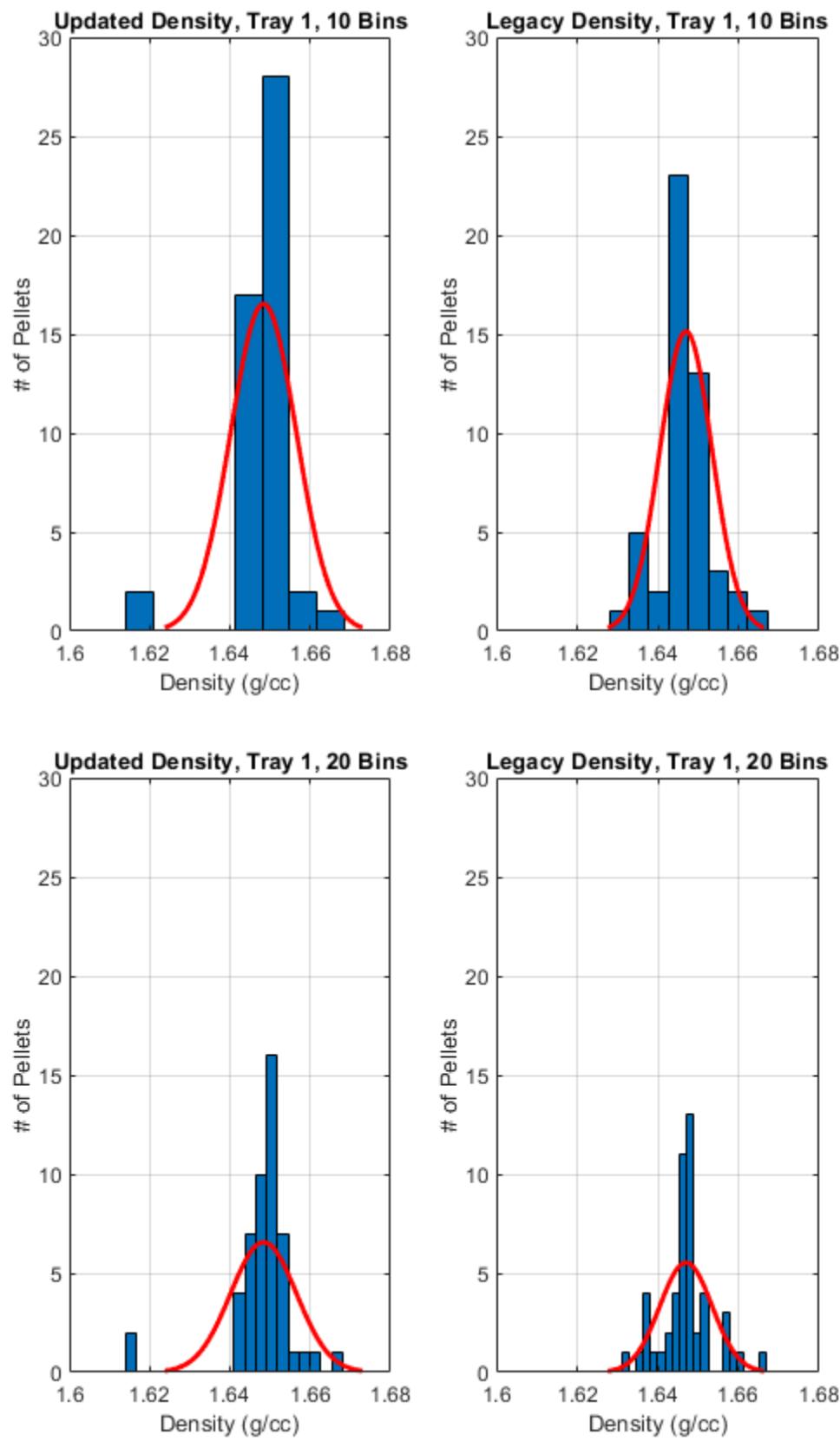
---

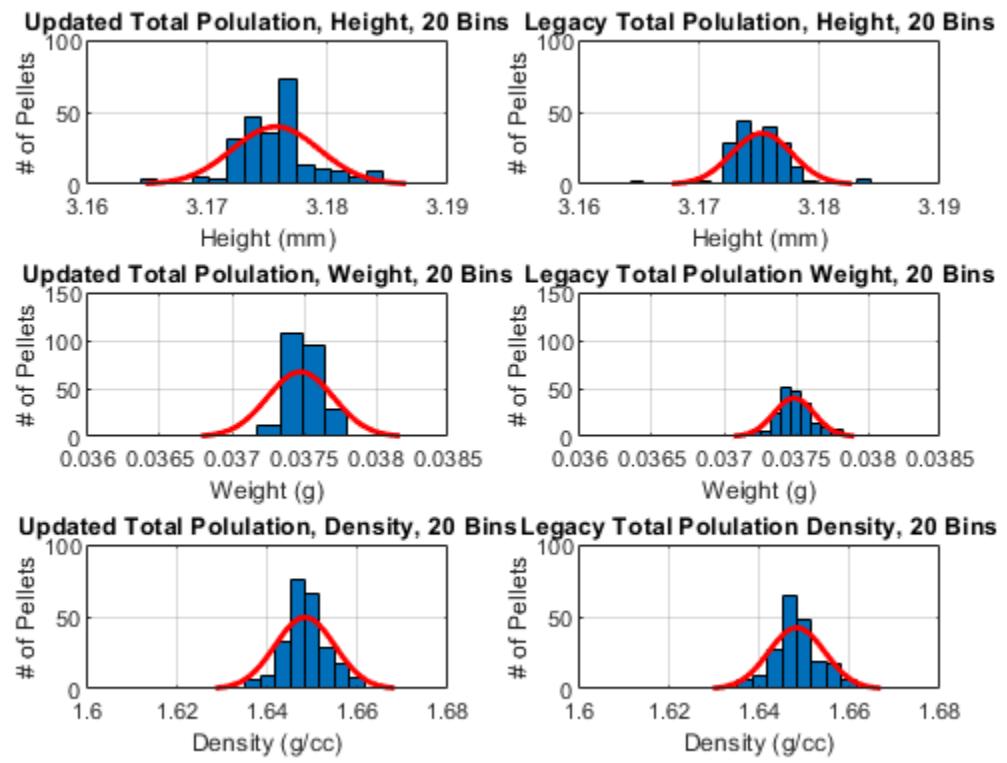
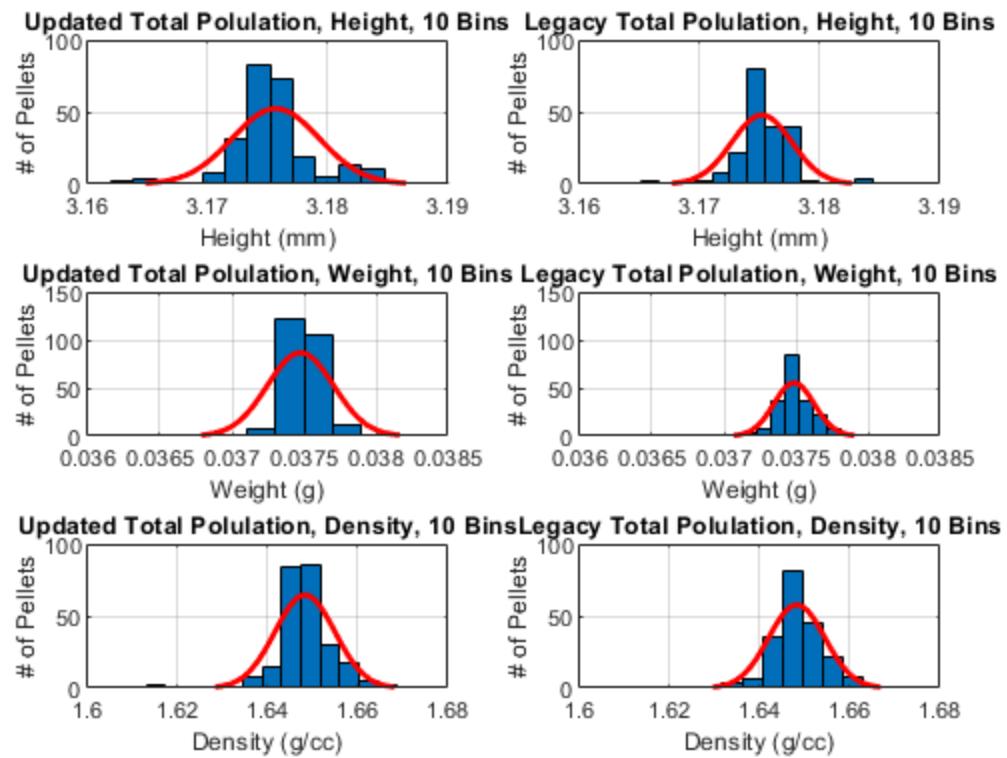
---

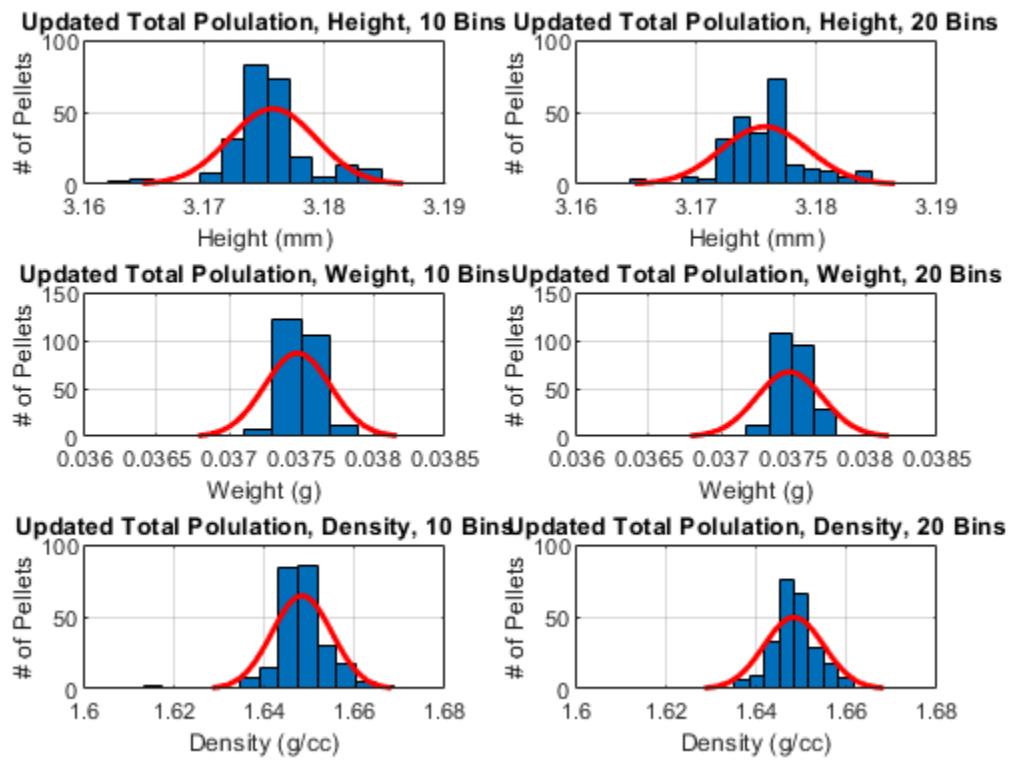
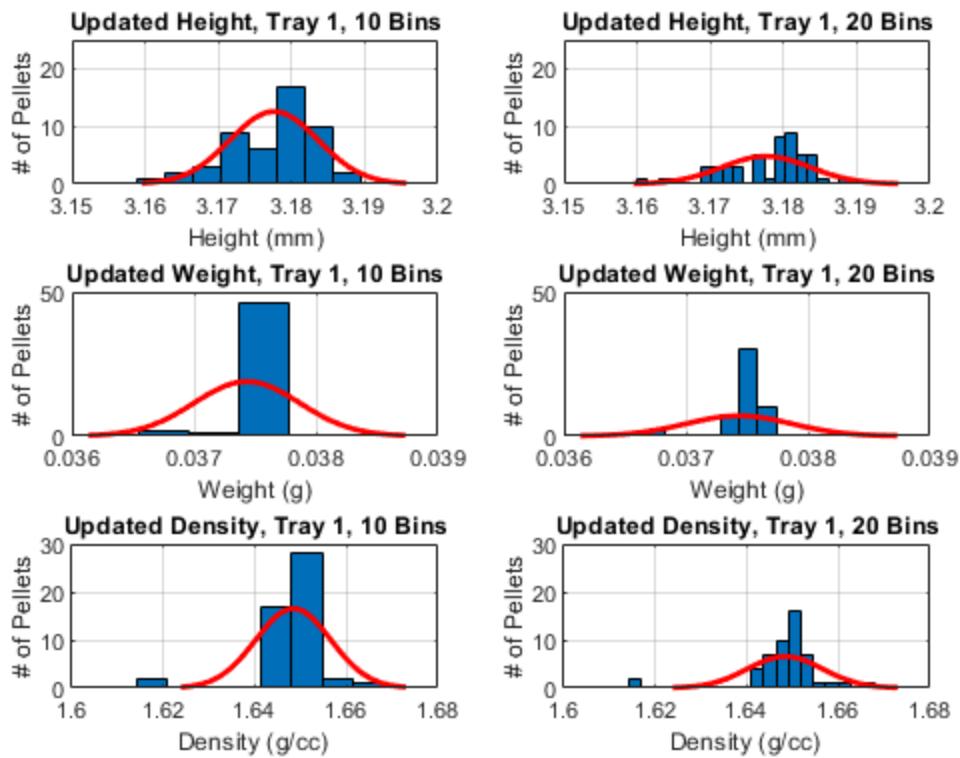
```
    xlim([0.0360 0.0385])
    ylabel('# of Pellets')
    ylim([0 150])
    grid on
    subplot(3,2,5)
    histfit(dlu)
    title('Updated Total Polulation, Density, 10 Bins')
    xlabel('Density (g/cc)')
    ylabel('# of Pellets')
    xlim([1.6 1.68])
    ylim([0 100])
    grid on
    subplot(3,2,2)
    histfit(hlu,20)
    title('Updated Total Polulation, Height, 20 Bins')
    xlabel('Height (mm)')
    xlim([3.16 3.19])
    ylabel('# of Pellets')
    ylim([0 100])
    grid on
    subplot(3,2,4)
    histfit(wlu,20)
    title('Updated Total Polulation, Weight, 20 Bins')
    xlabel('Weight (g)')
    xlim([0.0360 0.0385])
    ylabel('# of Pellets')
    ylim([0 150])
    grid on
    subplot(3,2,6)
    histfit(dlu,20)
    title('Updated Total Polulation, Density, 20 Bins')
    xlabel('Density (g/cc)')
    xlim([1.6 1.68])
    ylabel('# of Pellets')
    ylim([0 100])
    grid on
```











---

# Updated Data Testing

Parameters by Tray 1 Updated OD

```
[odtlu,odptlu,odstlu] = chi2gof(odu(:,1)); % chisquare test

% Updated Height
[htlu,hptlu,hstlu] = chi2gof(hu(:,1));

% Updated Weight
[wtlu,wptlu,wstlu] = chi2gof(wu(:,1));

% Updated Density
[dtlu,dptlu,dstlu] = chi2gof(du(:,1));

% Updated Data by Parameter (Legacy Tray 1-4 + Updated Tray 1)
[od1lu,odlplu,odls1lu] = chi2gof(odlu); % chisquare test
[h1lu,hlp1lu,hls1lu] = chi2gof(hlu);
[w1lu,wlp1lu,wls1lu] = chi2gof(wlu);
[d1lu,dlp1lu,dls1lu] = chi2gof(dlu);

% Tabulate Results compared to Legacy Data
odtraytestu = {[{'0/1'} odtlu odt1;{'Pvalue'} odptlu odpt1];
UpdatedODTestStats = cell2table(odtraytestu,'VariableNames',
{'Hypothesis','Updated_Tray_1','Legacy_Tray_1'});

htraytestu = {[{'0/1'} htlu ht1;{'Pvalue'} hptlu hpt1];
UpdatedHTestStats = cell2table(htraytestu,'VariableNames',
{'Hypothesis','Updated_Tray_1','Legacy_Tray_1'});

wtraytestu = {[{'0/1'} wtlu wt1;{'Pvalue'} wptlu wpt1];
UpdatedWTestStats = cell2table(wtraytestu,'VariableNames',
{'Hypothesis','Updated_Tray_1','Legacy_Tray_1'});

dtraytestu = {[{'0/1'} dtlu dt1;{'Pvalue'} dptlu dpt1];
UpdatedDTestStats = cell2table(dtraytestu,'VariableNames',
{'Hypothesis','Updated_Tray_1','Legacy_Tray_1'});

Poptestu = {[{'0/1'} od1lu h1lu w1lu d1lu;{'Pvalue'} odlplu hlp1lu wlplu
dlplu];
UpdatedPopTestStats = cell2table(Poptestu,'VariableNames',
{'Hypothesis','OD','H','W','D'})}

UpdatedODTestStats =
2x3 table

Hypothesis Updated_Tray_1 Legacy_Tray_1
_____ _____ _____
'0/1' 1 0
```

---

```

'Pvalue'          4.8207e-19           NaN

UpdatedHTestStats =
2x3 table

Hypothesis      Updated_Tray_1      Legacy_Tray_1
_____
'0/1'            1                  1
'Pvalue'         0.042975        7.6876e-05

UpdatedWTestStats =
2x3 table

Hypothesis      Updated_Tray_1      Legacy_Tray_1
_____
'0/1'            0                  0
'Pvalue'         NaN                0.051421

UpdatedDTestStats =
2x3 table

Hypothesis      Updated_Tray_1      Legacy_Tray_1
_____
'0/1'            1                  1
'Pvalue'         1.8344e-05       0.00017105

UpdatedPopTestStats =
2x5 table

Hypothesis      OD          H          W          D
_____
'0/1'            1           1           0           1
'Pvalue'         1.3071e-38   4.2415e-10  NaN        6.5537e-06

```

## Updated Data Machine Sorting and Dendograms

Updated Height Euclidean Dendograms

---

```

ytesthlu = pdist(hu(:,1)); % tray 1
squareform(ytesthlu);
ztesthlu = linkage(ytesthlu);
ytesthtu = pdist(hlu(:,1)); % total population
squareform(ytesthtu);
ztesthtu = linkage(ytesthtu);

figure ('name','Updated Height Euclidean Dendrogram Tray 1')
dendrogram(ztesthlu,0)
title('Updated Height, Tray 1, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

figure ('name','Updated Height Euclidean Dendrogram, All Pellets')
dendrogram(ztesthtu,0)
title('Updated Height, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

% Updated Height Cityblock Dendograms
ytesth1cbu = pdist(hu(:,1),'cityblock'); % tray 1
squareform(ytesth1cbu);
ztesth1cbu = linkage(ytesth1cbu,'average');
ytesthtcbu = pdist(hlu(:,1),'cityblock'); % total population
squareform(ytesthtcbu);
ztesthtcbu = linkage(ytesthtcbu,'average');

figure ('name','Updated Height Cityblock Dendrogram Tray 1')
dendrogram(ztesth1cbu,0)
title('Updated Height, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

figure ('name','Updated Height Cityblock Dendrogram, All Pellets')
dendrogram(ztesthtcbu,0)
title('Updated Height, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

% Updated Weight Euclidean Dendograms
ytestwlu = pdist(wu(:,1)); % tray 1
squareform(ytestwlu);
ztestwlu = linkage(ytestwlu);
ytestwtu = pdist(wlu(:,1)); % total population
squareform(ytestwtu);
ztestwtu = linkage(ytestwtu);

figure ('name','Updated Weight Euclidean Dendrogram Tray 1')
dendrogram(ztestwlu,0)
title('Updated Weight, Tray 1, Euclidean')

```

---

---

```

xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

figure ('name','Updated Weight Euclidean Dendrogram, All Pellets')
dendrogram(ztestwtu,0)
title('Updated Weight, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

% Updated Weight Cityblock Dendograms
ytestwlcbu = pdist(wu(:,1),'cityblock'); % tray 1
squareform(ytestwlcbu);
ztestwlcbu = linkage(ytestwlcbu,'average');
ytestwtcbu = pdist(wlu(:,1),'cityblock'); % total population
squareform(ytestwtcbu);
ztestwtcbu = linkage(ytestwtcbu,'average');

figure ('name','Updated Weight Cityblock Dendrogram Tray 1')
dendrogram(ztestwlcbu,0)
title('Updated Weight, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

figure ('name','Updated Weight Cityblock Dendrogram, All Pellets')
dendrogram(ztestwtcbu,0)
title('Updated Weight, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

% Updated Density Euclidean Dendograms
ytestdlu = pdist(du(:,1)); % tray 1
squareform(ytestdlu);
ztestdlu = linkage(ytestdlu);
ytestdtu = pdist(dlu(:,1)); % total population
squareform(ytestdtu);
ztestdtu = linkage(ytestdtu);

figure ('name','Updated Density Euclidean Dendrogram Tray 1')
dendrogram(ztestdlu,0)
title('Updated Density, Tray 1, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

figure ('name','Updated Density Euclidean Dendrogram, All Pellets')
dendrogram(ztestdtu,0)
title('Updated Density, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

```

---

---

```

% Updated Density Cityblock Dendograms
ytestdlcbu = pdist(du(:,1),'cityblock'); % tray 1
squareform(ytestdlcbu);
ztestdlcbu = linkage(ytestdlcbu,'average');
ytestdtcbu = pdist(dlu(:,1),'cityblock'); % total population
squareform(ytestdtcbu);
ztestdtcbu = linkage(ytestdtcbu,'average');

figure ('name','Updated Density Cityblock Dendrogram Tray 1')
dendrogram(ztestdlcbu,0)
title('Updated Density, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

figure('name','Updated Density and Legacy Density Cityblock Dendrogram
Tray 1')
subplot(2,1,1)
dendrogram(ztestdlcbu,0)
title('Updated Density, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,1,2)
dendrogram(ztestdlcb,0)
title('Legacy Density, Tray 1, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

figure ('name','Updated Density Cityblock Dendrogram, All Pellets')
dendrogram(ztestdtcbu,0)
title('Updated Density, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

figure('name','Updated and Legacy Density Cityblock Dendragraph All
Pellets')
subplot(2,1,1)
dendrogram(ztestdtcbu,0)
title('Updated Density, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])
subplot(2,1,2)
dendrogram(ztestdtcb,0)
title('Legacy Density, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

% Updated All Parameters Euclidean Dendograms

```

---

---

```

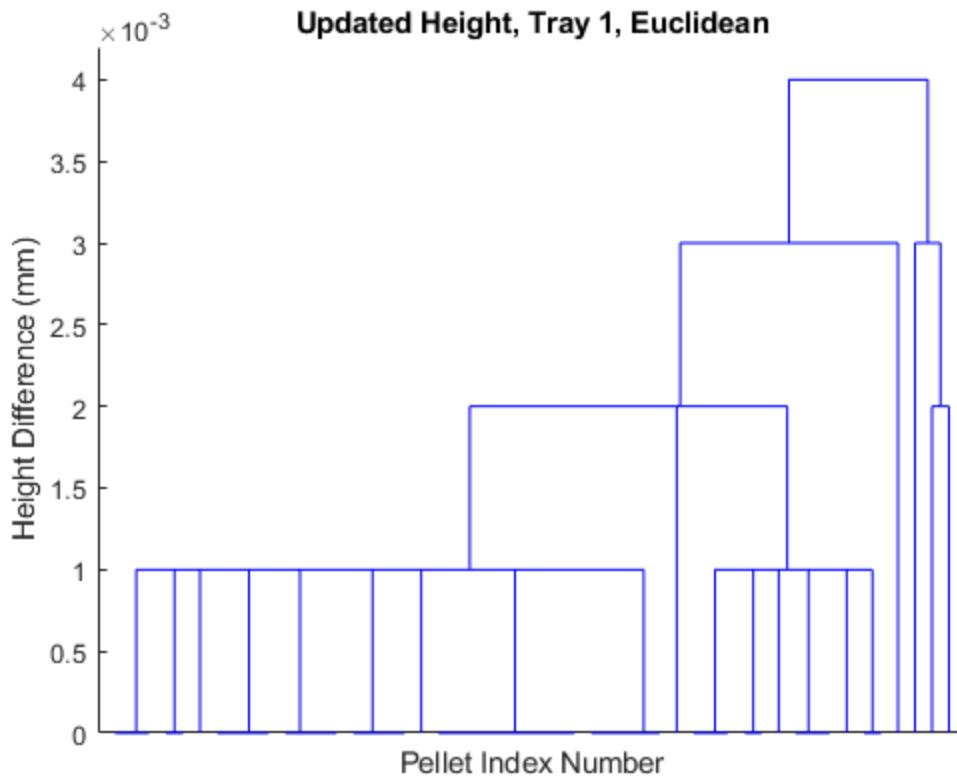
ytestalu = pdist(alu);
squareform(ytestalu);
ztestalu = linkage(ytestalu);

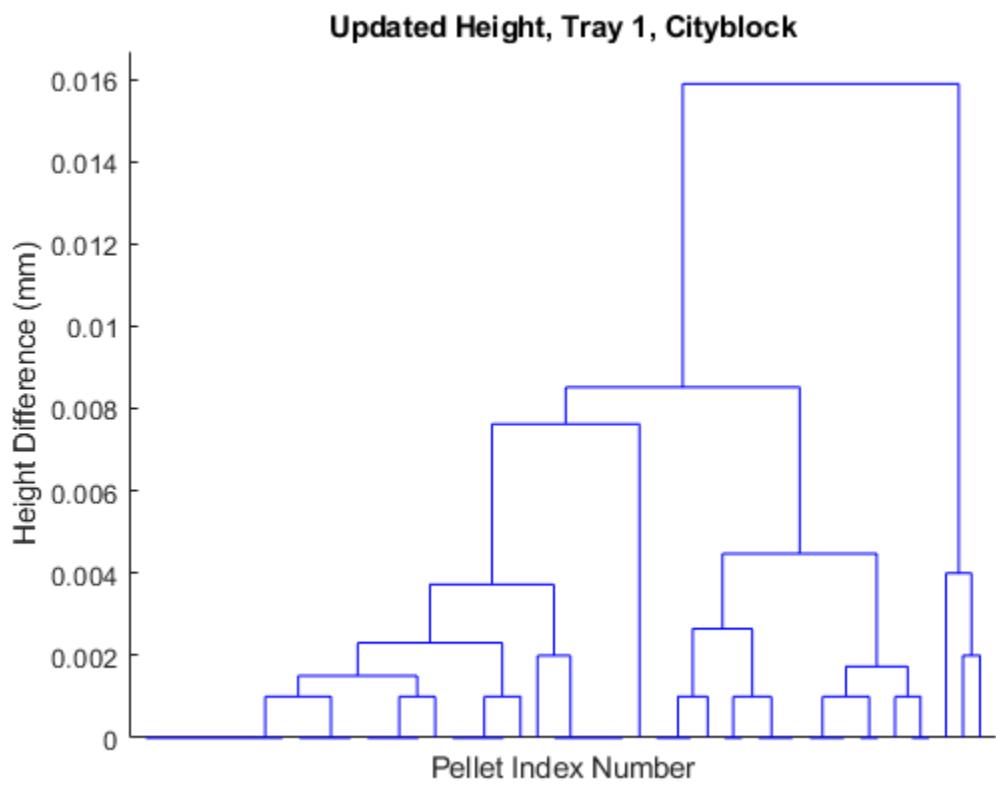
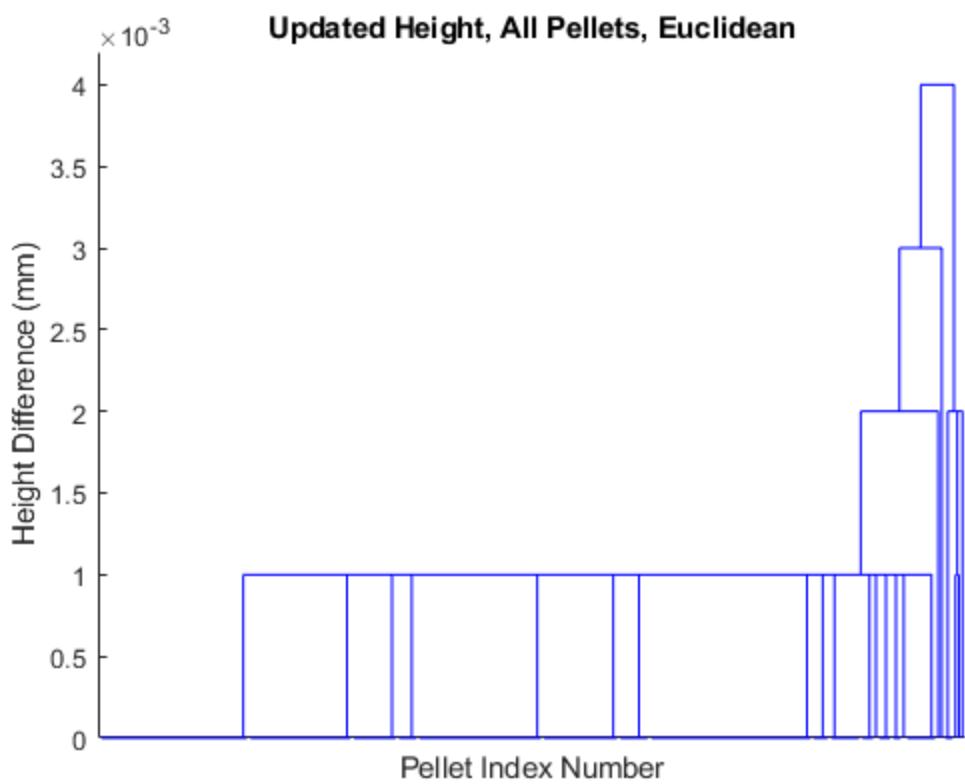
figure ('name','Updated All Parameters Euclidean Dendrogram, All
Pellets')
dendrogram(ztestalu,0)
title('Updated All Parameters, All Pellets, Euclidean')
xlabel('Pellet Index Number')
ylabel('Difference')
set(gca,'xtick',[])

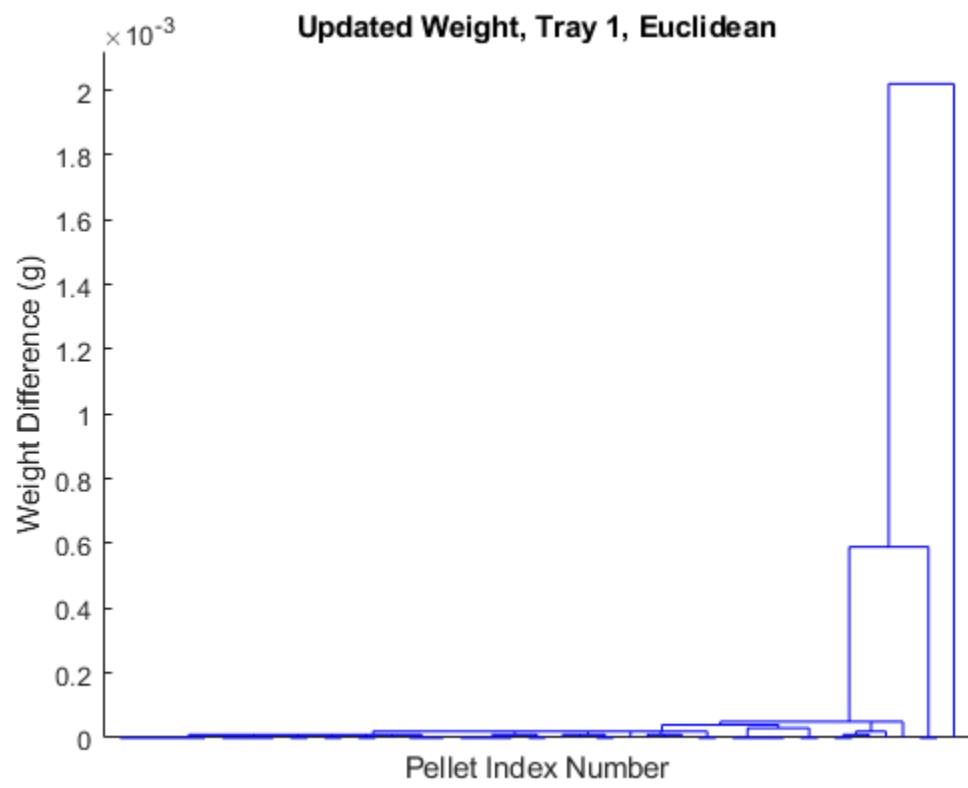
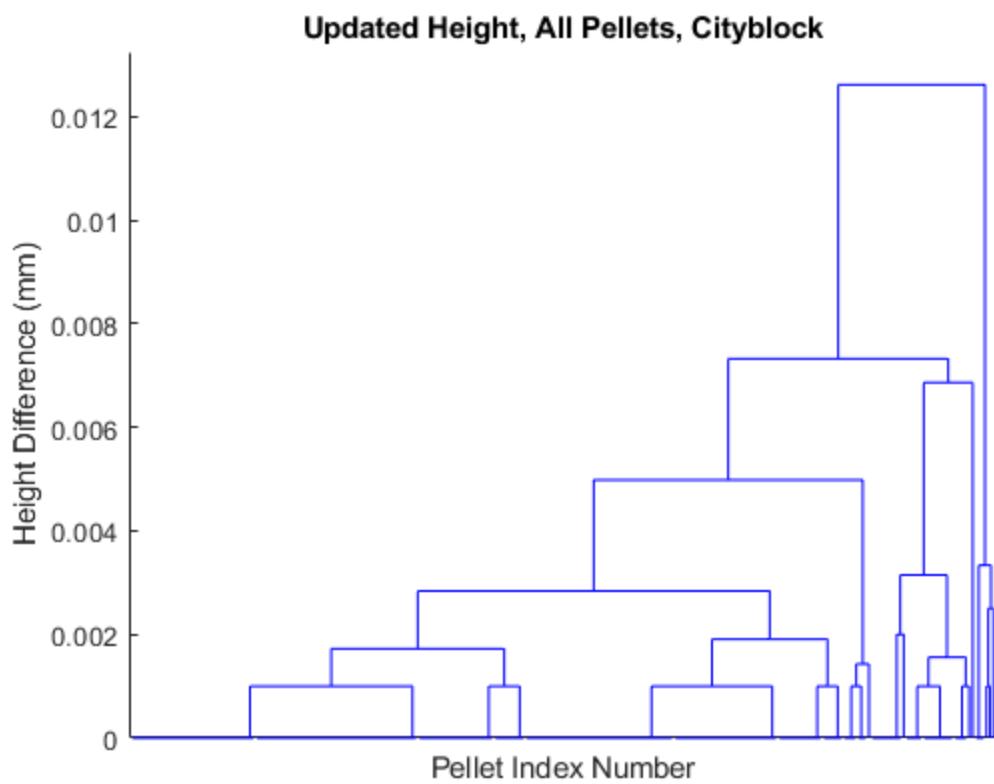
% Updated All Parameters Cityblock Dendrograms
ytestalcbu = pdist(alu,'cityblock');
squareform(ytestalcbu);
ztestalcbu = linkage(ytestalcbu, 'average');

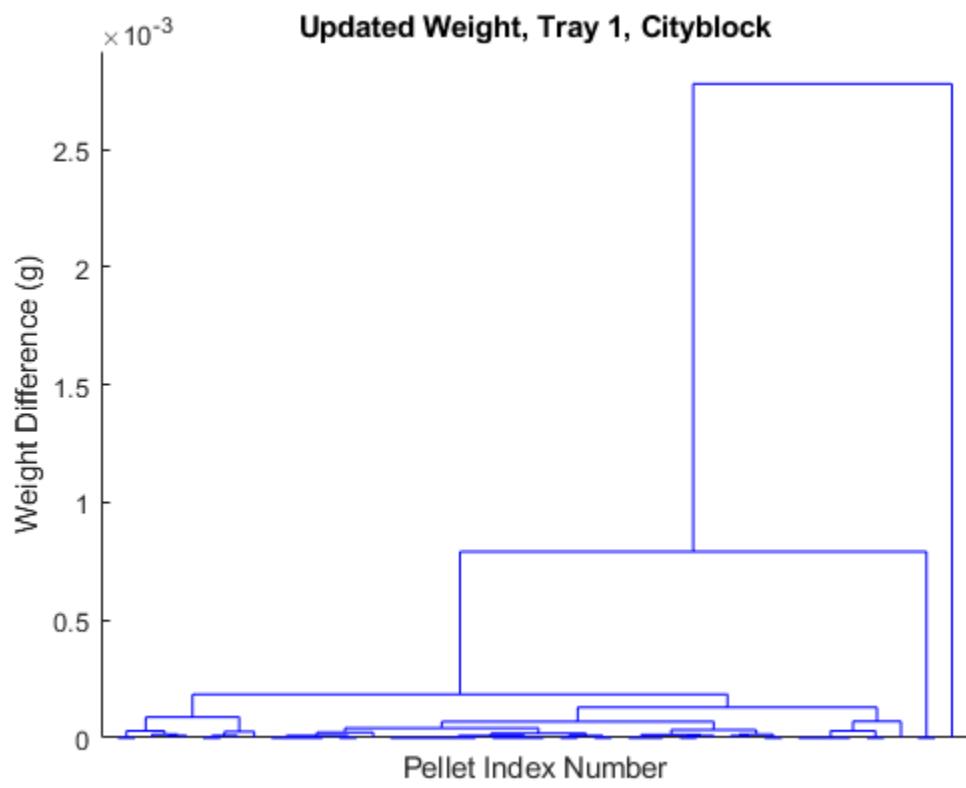
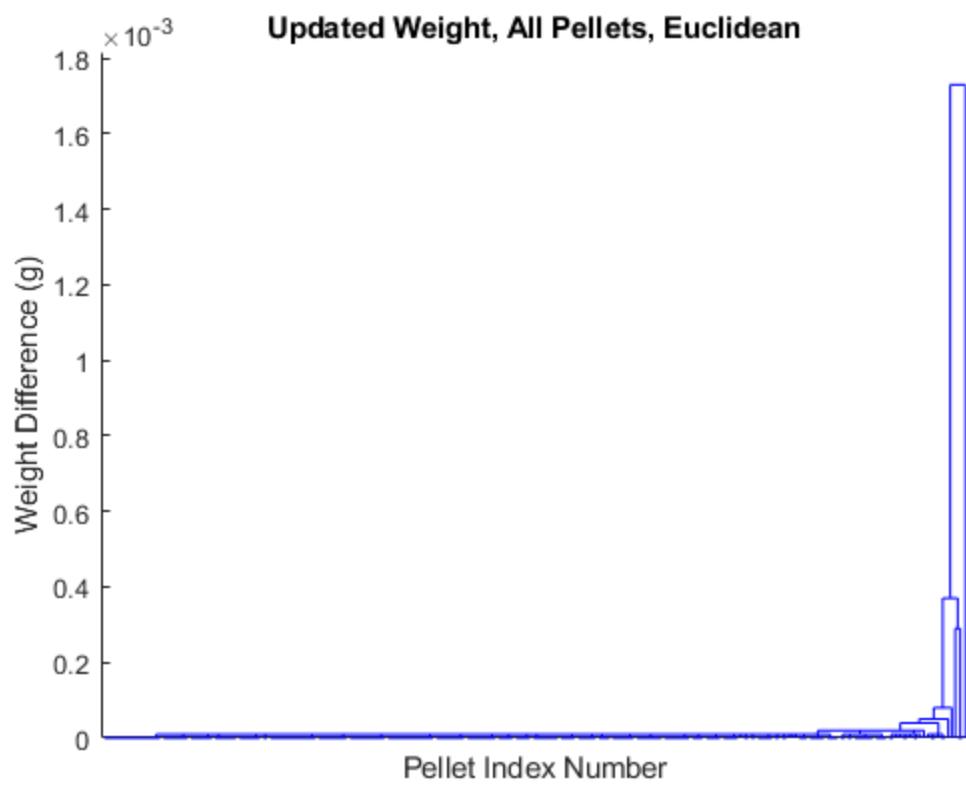
figure ('name','Updated All Parameters Cityblock Dendrogram, All
Pellets')
dendrogram(ztestalcbu,0)
title('Updated All Parameters, All Pellets, Cityblock')
xlabel('Pellet Index Number')
ylabel('Difference')
set(gca,'xtick',[])

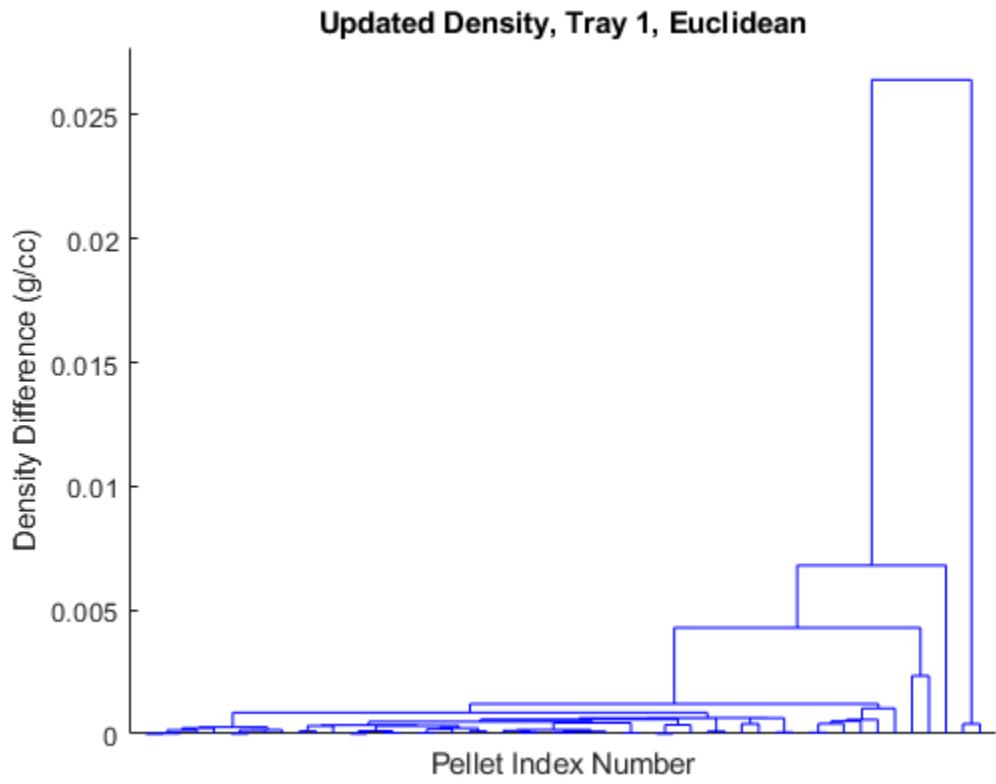
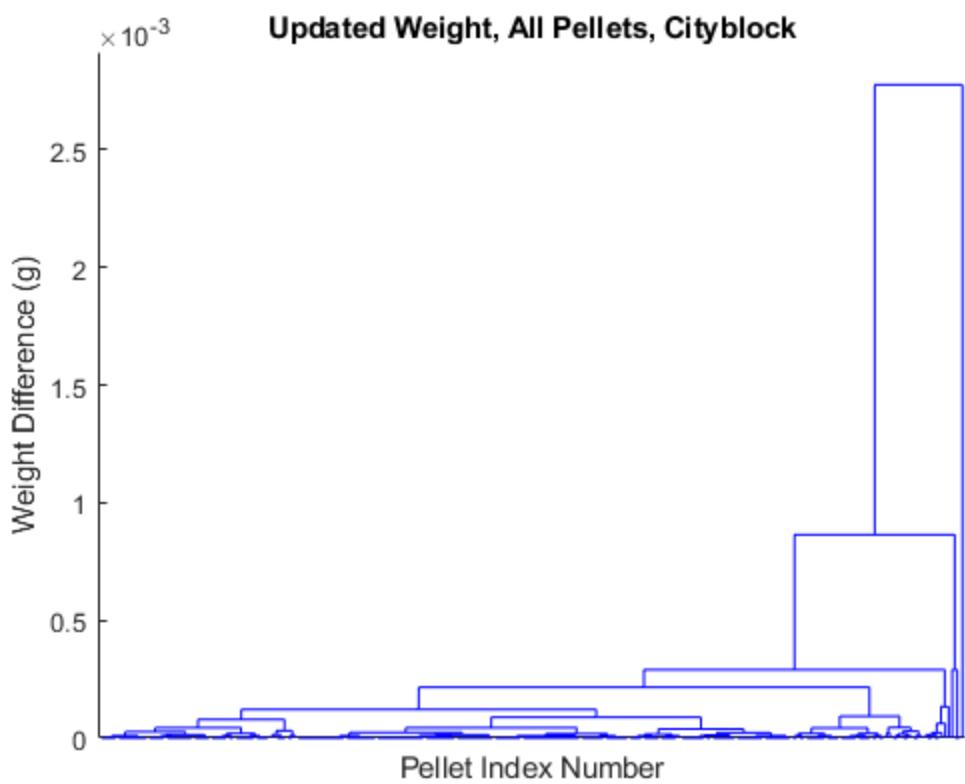
```

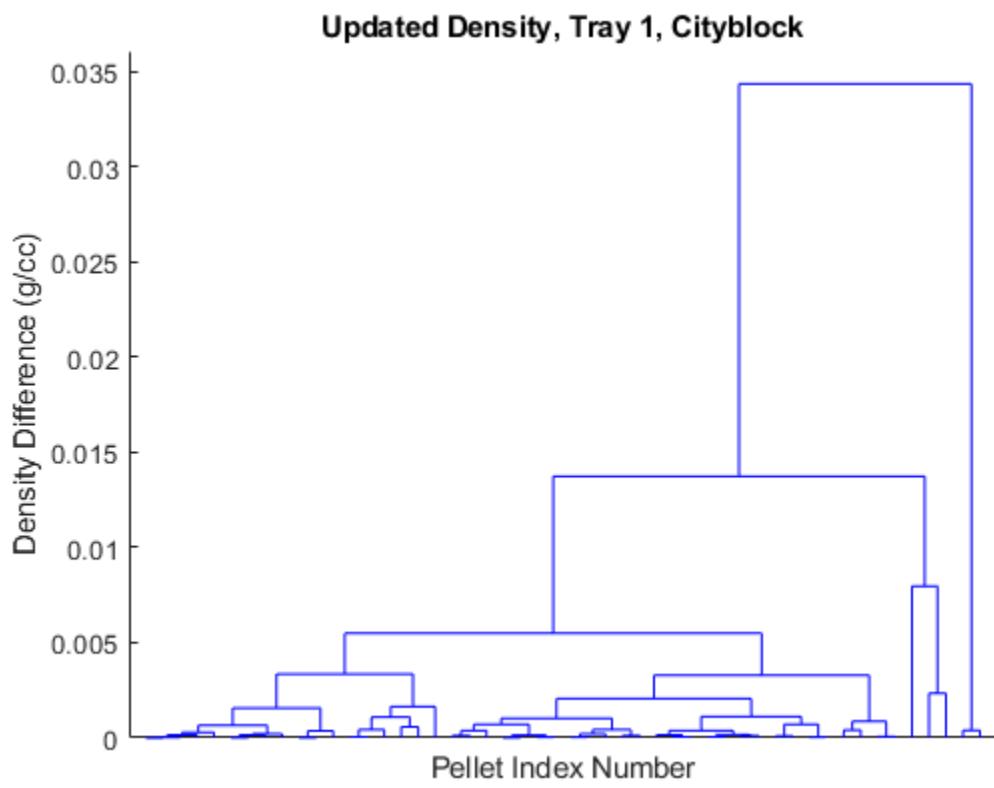
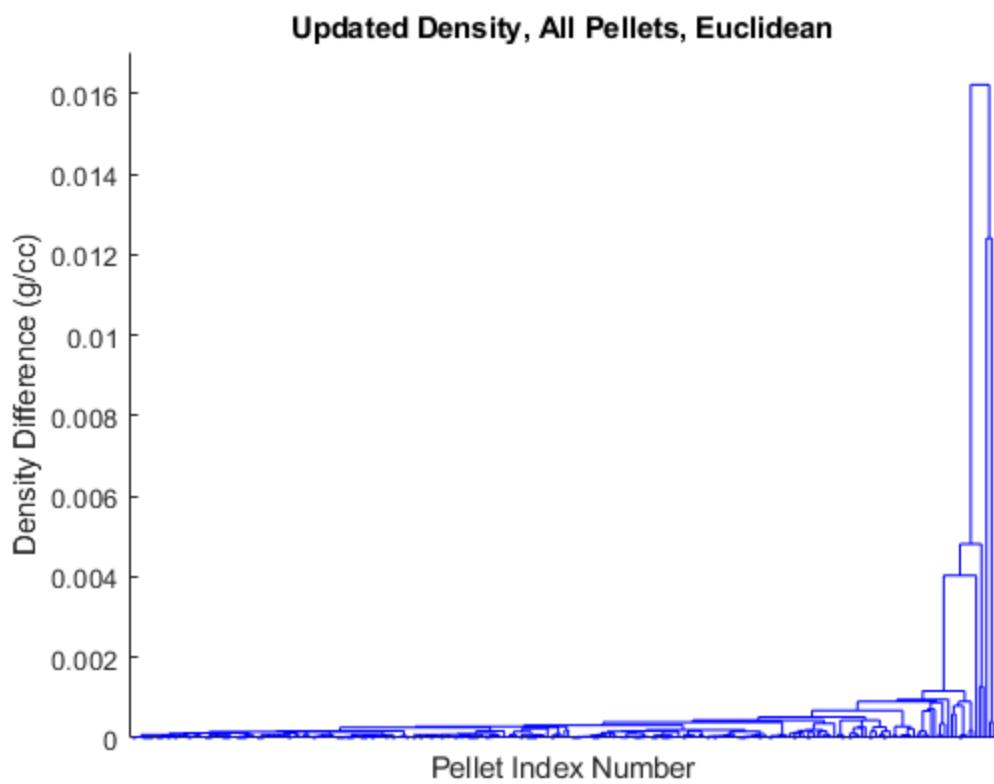


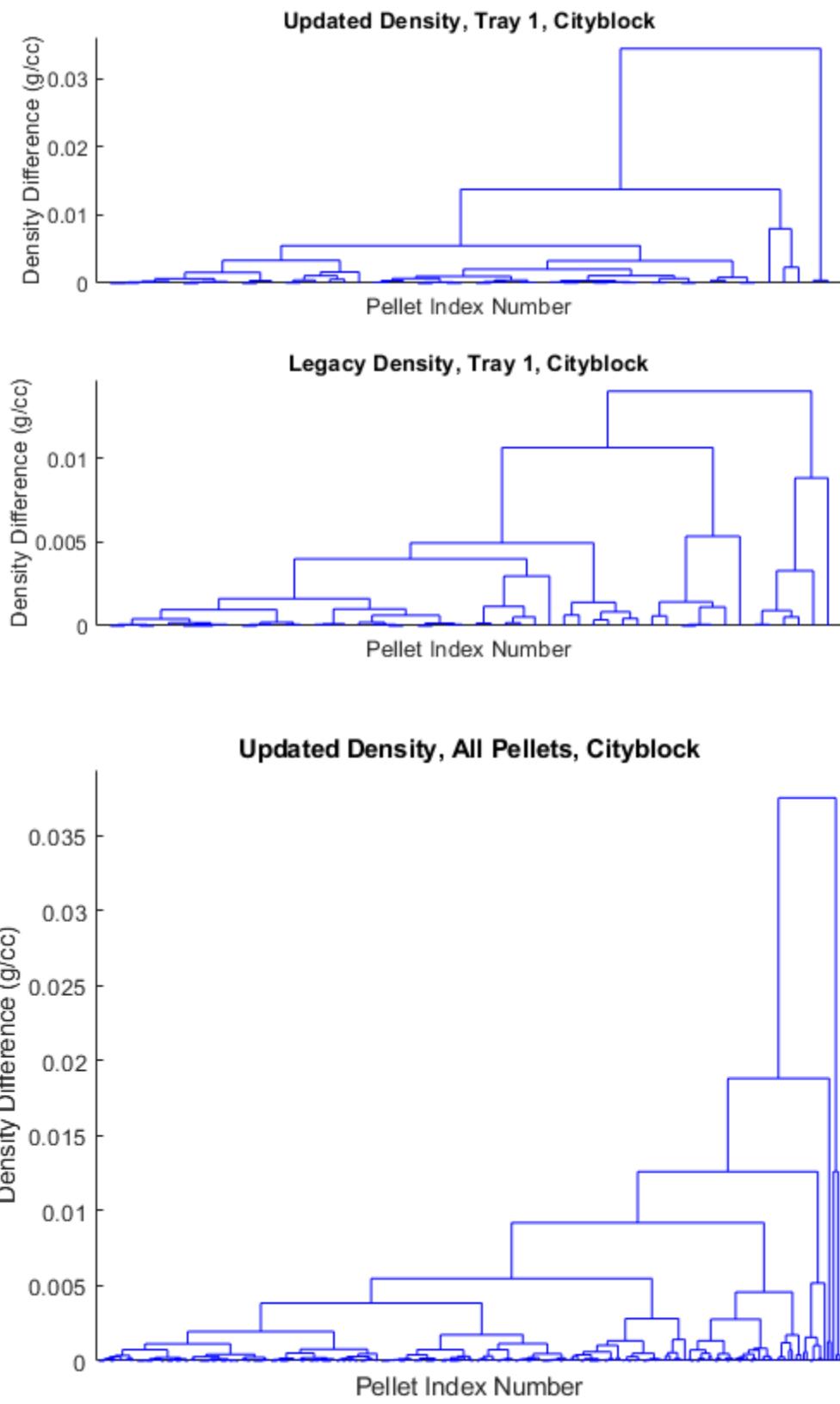


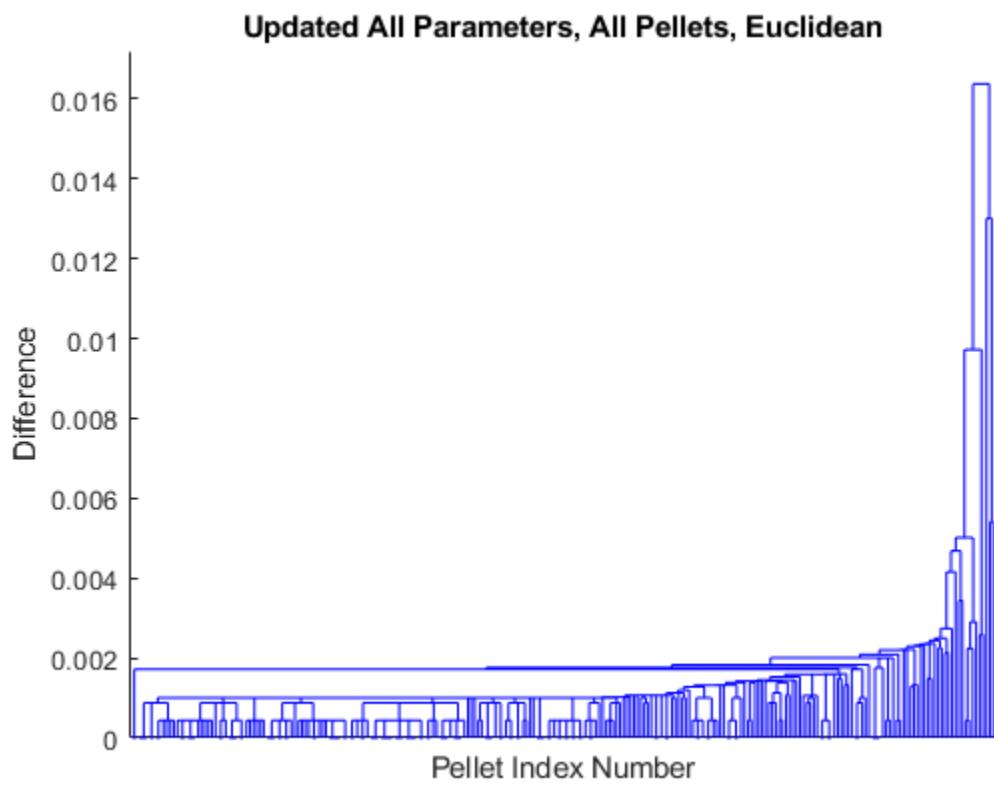
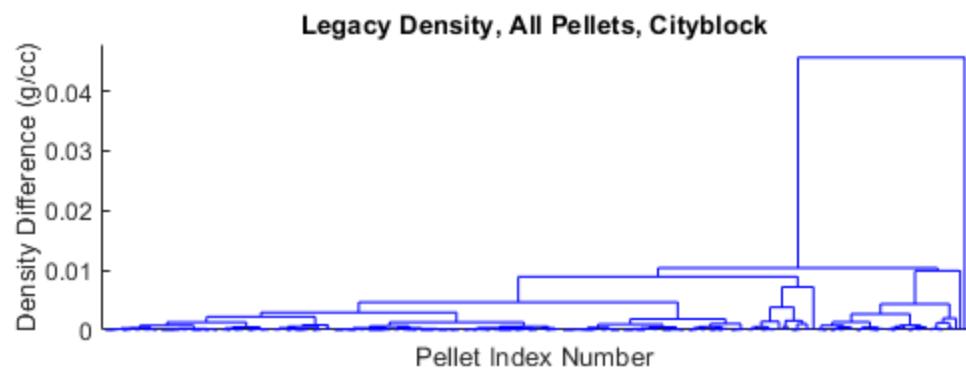
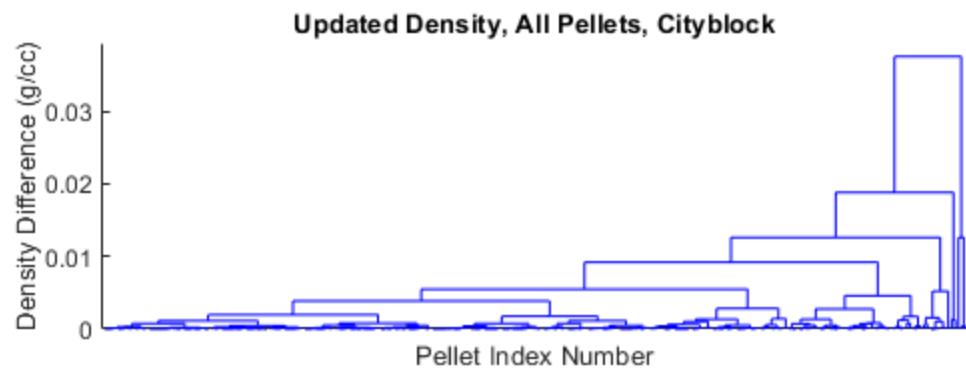


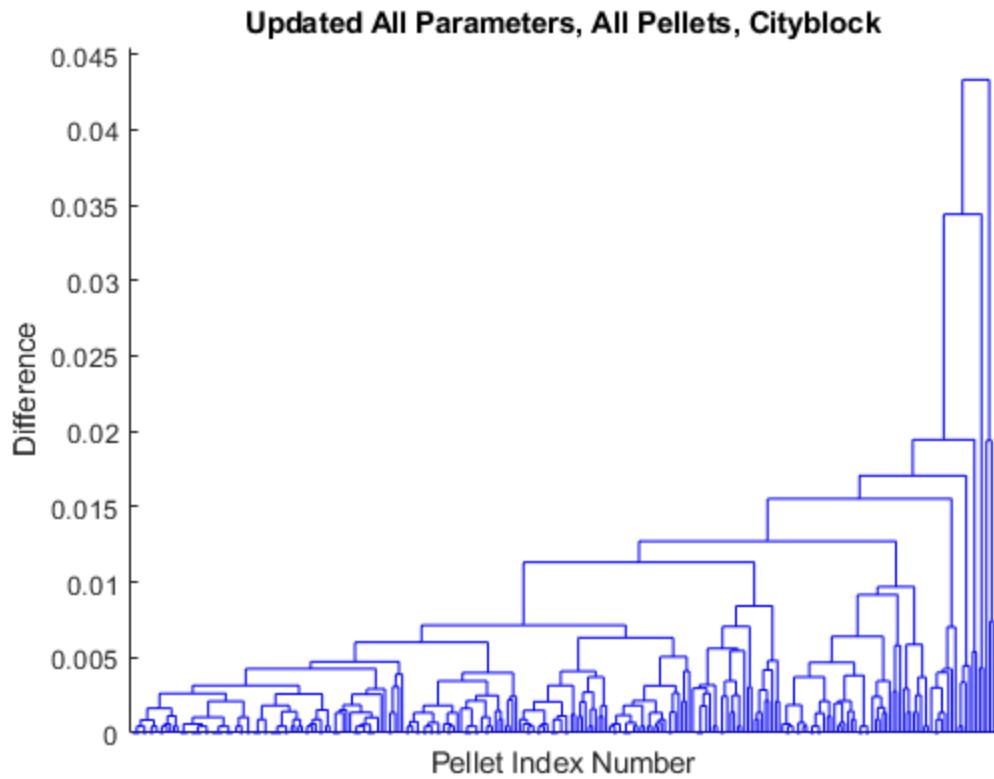












## Updated Data Cophenetic Distances and Inconsistency Coefficients

```
% Euclidean Cophenetic Distances, Height
chleu = cophenet(ztesthlu,ytesthlu);
chteu = cophenet(ztesthtu,ytesthtu);
challeu = [chleu cteu];
% Cityblock Cophenetic Distances, Height
ch1cbu = cophenet(ztesth1cbu,ytesth1cbu);
chtcbu = cophenet(ztesthtcbu,ytesthtcbu);
challcbu = [ch1cbu chtcbu];
% Maximum Inconsistency Coefficient, using Cityblock, Height
ih1cbu = inconsistent(ztesth1cbu);
ih1cbmaxu = max(ih1cbu(:,4));
ihtcbu = inconsistent(ztesthtcbu);
ihtcbmaxu = max(ihtcbu(:,4));
ihmaxallcbu = [ih1cbmaxu ihtcbmaxu];

% Euclidean Cophenetic Distances, Weight
cwleu = cophenet(ztestwlu,ytestwlu);
cwteu = cophenet(ztestwtu,ytestwtu);
cwalleu = [cwleu cwteu];
% Cityblock Cophenetic Distances, Weight
cw1cbu = cophenet(ztestwlcbu,ytestwlcbu);
```

---

```

cwtcbu = cophenet(ztestwtcbu,ytestwtcbu);
cwallcbu = [cw1cbu cwtcbu];
% Maximum Inconsistency Coefficient, using Cityblock, Weight
iw1cbu = inconsistent(ztestw1cbu);
iw1cbmaxu = max(iw1cbu(:,4));
iwtcbu = inconsistent(ztestwtcbu);
iwtcbmaxu = max(iwtcbu(:,4));
iwmallcbu = [iw1cbmaxu iwtcbmaxu];

% Euclidean Cophenetic Distances, Density
cdleu = cophenet(ztestd1lu,ytestd1lu);
cdteu = cophenet(ztestdtu,ytestdtu);
cdalleu = [cdleu cdteu];
% Cityblock Cophenetic Distances, Density
cd1cbu = cophenet(ztestd1cbu,ytestd1cbu);
cdtcbu = cophenet(ztestdtcbu,ytestdtcbu);
cdallcbu = [cd1cbu cdtcbu];
% Maximum Inconsistency Coefficient, using Cityblock, Density
id1cbu = inconsistent(ztestd1cbu);
id1cbmaxu = max(id1cbu(:,4));
idtcbu = inconsistent(ztestdtcbu);
idtcbmaxu = max(idtcbu(:,4));
idmaxallcbu = [id1cbmaxu idtcbmaxu];

% Updated Euclidean Cophenetic Distances, All Parameters
caleu = cophenet(ztestalu,ytestalu);

% Updated Cityblock Cophenetic Distances, All Parameters
calcbu = cophenet(ztestalcbu,ytestalcbu);

% Updated Maximum Inconsistency Coefficient, using Cityblock, All
% Parameters
ialeu = inconsistent(ztestalu);
ialemaxu = max(ialeu(:,4));
ialcbu = inconsistent(ztestalcbu);
ialcbmaxu = max(ialcbu(:,4));

% Tabulate Results (6 is Updated Tray 1, 7 is Updated Population )
copstatable2u = [6 ch1eu ch1cbu ih1cbmaxu cw1eu cw1cbu iw1cbmaxu
    cd1eu cd1cbu id1cbmaxu;7 chteu chtcbu ihtcbmaxu cwteu cwtcbu
    iw tcbmaxu cdteu cdtcbu idtcbmaxu];
UpdatedSortStats = array2table(copstatable2u,'VariableNames',
{'Tray','HCDE','HDCDB','HIC','WCDE','WCDCB','WIC','DCDE','DCDCB','DIC'});
copstatable2alu = [caleu calcbu ialemaxu ialcbmaxu];
UpdatedAllParaStats = array2table(copstatable2alu,'VariableNames',
{'APCDE','APCDCB','APICE','APICCB'});

% Compare Results (1 -4 are Legacy Trays 1-4, 5 is Legacy Population,
% 6 is Updated Tray 1, and 7 is Updated Population)
copstatable2ut = [1 ch1e ch1cb ih1cbmax cw1e cw1cb iwlcbmax cd1e
    cd1cb id1cbmax;2 ch2e ch2cb ih2cbmax cw2e cw2cb iw2cbmax cd2e
    cd2cb id2cbmax;3 ch3e ch3cb ih3cbmax cw3e cw3cb iw3cbmax cd3e
    cd3cb id3cbmax;4 ch4e ch4cb ih4cbmax cw4e cw4cb iw4cbmax cd4e
    cd4cb id4cbmax;5 chte chtcb ihtcbmax cwte cwtcb iw tcbmax cdte cdtcb
    ];

```

---

---

```

id tcbmax;6 chleu chlcbu ihlcbmaxu cwleu cwlcbu iwlcmaxu cd1eu cd1cbu
id1cbmaxu;7 chteu chtcbu ihtcbmaxu cwteu cwtcbu iwtcbmaxu cdteu
cdtcbu idtcbmaxu];
CompareSortStats = array2table(copstattable2ut, 'VariableNames',
{'Tray', 'HCDE', 'HCDCB', 'HIC', 'WCDE', 'WDCB', 'WIC', 'DCDE', 'DCDCB', 'DIC'});
copstattable2aluc = [cale calcb ialemax ialcbmax;caleu calcbu ialemaxu
ialcbmaxu];
UpdatedAllParaStatsComp =
array2table(copstattable2aluc, 'VariableNames',
{'APCDE', 'APCDCB', 'APICE', 'APICCB'})

```

*UpdatedSortStats* =

2×10 table

<i>Tray</i>	<i>HCDE</i>	<i>HCDCB</i>	<i>HIC</i>	<i>WCDE</i>	<i>WDCB</i>	<i>WIC</i>
<i>DCDE</i>	<i>DCDCB</i>	<i>DIC</i>				
6	0.82465	0.83915	1.1547	0.98945	0.993	
1.1547	0.93574	0.95673	1.1544			
7	0.69646	0.87164	1.1547	0.93488	0.9697	
1.1547	0.80338	0.89999	1.1547			

*UpdatedAllParaStats* =

1×4 table

<i>APCDE</i>	<i>APCDCB</i>	<i>APICE</i>	<i>APICCB</i>
0.82544	0.87859	1.1547	1.1547

*CompareSortStats* =

7×10 table

<i>Tray</i>	<i>HCDE</i>	<i>HCDCB</i>	<i>HIC</i>	<i>WCDE</i>	<i>WDCB</i>	<i>WIC</i>
<i>DCDE</i>	<i>DCDCB</i>	<i>DIC</i>				
1	0.93743	0.94557	1.1547	0.81668	0.79689	
1.1547	0.8436	0.84029	1.1547			
2	0.59532	0.78111	1.1547	0.90152	0.95006	
1.1547	0.88467	0.95036	1.1514			
3	0.54903	0.74655	1.1547	0.73311	0.792	
1.1547	0.81439	0.80456	1.148			
4	0.77063	0.8572	1.1547	0.64288	0.70384	
1.1547	0.67874	0.75449	1.1547			

---

5	0.87666	0.90168	1.1547	0.75019	0.88367
1.1547	0.72992	0.8686	1.1547		
6	0.82465	0.83915	1.1547	0.98945	0.993
1.1547	0.93574	0.95673	1.1544		
7	0.69646	0.87164	1.1547	0.93488	0.9697
1.1547	0.80338	0.89999	1.1547		

*UpdatedAllParaStatsComp =*

*2x4 table*

<i>APCDE</i>	<i>APCDCB</i>	<i>APICE</i>	<i>APICCB</i>
0.76597	0.87306	1.1547	1.1547
0.82544	0.87859	1.1547	1.1547

## Updated Data Clustering

Tray Index Assignment for Clustering (add to original index)

```

tray(201:250) = {'Tray 1 - Updated'};

thu = cluster(ztesthtcbu,'maxclust',4);
UpdatedHeightSort = crosstab(thu,tray)
cutoff4 = median([ztesthtcbu(end-2,3) ztesthtcbu(end-1,3)]);
figure('name','Updated 4 Sorted Height Dendrogram')
dendrogram(ztesthtcbu,0,'ColorThreshold',cutoff4)
title('Updated Height, 4 Cluster')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

twu = cluster(ztestwtcbu,'maxclust',4);
UpdatedWeightSort = crosstab(twu,tray)
cutoff5 = median([ztestwtcbu(end-2,3) ztestwtcbu(end-1,3)]);
figure('name','Updated 4 Sorted Weight Dendrogram')
dendrogram(ztestwtcbu,0,'ColorThreshold',cutoff5)
title('Updated Weight, 4 Cluster')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

tdu = cluster(ztestdtcbu,'maxclust',4);
UpdatedDensitySort = crosstab(tdu,tray)
cutoff6 = median([ztestdtcb(end-2,3) ztestdtcb(end-1,3)]);
figure('name','Updated 4 Sorted Density Dendrogram')
dendrogram(ztestdtcbu,0,'ColorThreshold',cutoff6)
title('Updated Density, 4 Cluster')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')

```

---

```

set(gca,'xtick',[])

tal = cluster(ztestalcbu,'maxclust',4);
UpdatedAllParaSort = crosstab(tal,tray)
cutoffal4 = ztestalcbu(end-2,3);
figure('name','Updated 4 Sorted All Parameter Dendrogram')
dendrogram(ztestalcbu,0,'ColorThreshold',cutoffal4)
title('Updated All Parameter, 4 Cluster, Cityblock')
xlabel('Pellet Index Number')
ylabel('Difference (unitless)')
set(gca,'xtick',[])

% Display Updated 4 Clustered Results
figure('name','Updated Height vs. Weight vs. Density, All Pellets, 4
Cluster')
map = [1 0 0; 0.25 0.75 0.25; 0 0 1; 0.75 0 0.75];
colormap(map)
scatter3(hlu,wlu,dlu,10,tal,'filled')
xlabel('Height (mm)')
ylabel('Weight (g)')
zlabel('Density (g/cc)')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
title('Updated Measurements, 4 Cluster, Cityblock')

% Try 5 Clusters
thu5 = cluster(ztesthtcbu,'maxclust',5);
UpdatedHeightSort5 = crosstab(thu5,tray)
cutoff7 = median([ztesthtcbu(end-3,3) ztesthtcbu(end-2,3)
ztesthtcbu(end-1,3)]);
figure('name','Updated 5 Sorted Height Dendrogram')
dendrogram(ztesthtcbu,0,'ColorThreshold',cutoff7)
title('Updated Height, 5 Cluster')
xlabel('Pellet Index Number')
ylabel('Height Difference (mm)')
set(gca,'xtick',[])

twu5 = cluster(ztestwtcbu,'maxclust',5);
UpdatedWeightSort5 = crosstab(twu5,tray)
cutoff8 = median([ztestwtcbu(end-3,3) ztestwtcbu(end-2,3)
ztestwtcbu(end-1,3)]);
figure('name','Updated 5 Sorted Weight Dendrogram')
dendrogram(ztestwtcbu,0,'ColorThreshold',cutoff8)
title('Updated Weight, 5 Cluster')
xlabel('Pellet Index Number')
ylabel('Weight Difference (g)')
set(gca,'xtick',[])

tdu5 = cluster(ztestdtcbu,'maxclust',5);
UpdatedDensitySort5 = crosstab(tdu5,tray)
cutoff9 = median([ztestdtcb(end-3,3) ztestdtcb(end-2,3)
ztestdtcb(end-1,3)]);
figure('name','Updated 5 Sorted Density Dendrogram')

```

---

---

```

dendrogram(ztestdtcbu,0,'ColorThreshold',cutoff9)
title('Updated Density, 5 Cluster')
xlabel('Pellet Index Number')
ylabel('Density Difference (g/cc)')
set(gca,'xtick',[])

talu5 = cluster(ztestalcbu,'maxclust',5);
UpdatedAllParaSort5 = crosstab(talu5,tray)
cutoffalu5 = ztestalcbu(end-3,3);
figure('name','Updated 4 Sorted All Parameter Dendrogram')
dendrogram(ztestalcbu,0,'ColorThreshold',cutoffalu5)
title('Updated All Parameter, 5 Cluster, Cityblock')
xlabel('Pellet Index Number')
ylabel('Difference (unitless)')
set(gca,'xtick',[])

% Display Clustered Results
figure('name','Updated Height vs. Weight vs. Density, All Pellets, 5
Cluster')
map = [0.75 0 0.75; 0.75 0.75 0; 1 0 0; 0.25 0.75 0.25; 0 0 1];
colormap(map)
scatter3(hlu,wlu,dlu,10,talu5,'filled')
xlabel('Height (mm)')
ylabel('Weight (g)')
zlabel('Density (g/cc)')
xlim([3.16 3.19])
ylim([0.0360 0.0380])
zlim([1.60 1.70])
title('Updated Measurements, 5 Cluster, Cityblock')
grid on

```

*UpdatedHeightSort* =

0	0	0	0	1
4	0	1	0	24
43	50	49	50	22
3	0	0	0	3

*UpdatedWeightSort* =

7	0	1	0	0
43	49	49	50	47
0	1	0	0	2
0	0	0	0	1

*UpdatedDensitySort* =

0	1	0	0	0
0	0	0	0	2
1	0	0	0	1
49	49	50	50	47

---

*UpdatedAllParaSort* =

0	0	0	0	2
<b>49</b>	<b>49</b>	<b>50</b>	<b>50</b>	<b>45</b>
1	0	0	0	1
0	1	0	0	2

*UpdatedHeightSort5* =

0	0	0	2	6
<b>43</b>	<b>50</b>	<b>49</b>	<b>48</b>	<b>16</b>
0	0	0	0	1
4	0	1	0	24
3	0	0	0	3

*UpdatedWeightSort5* =

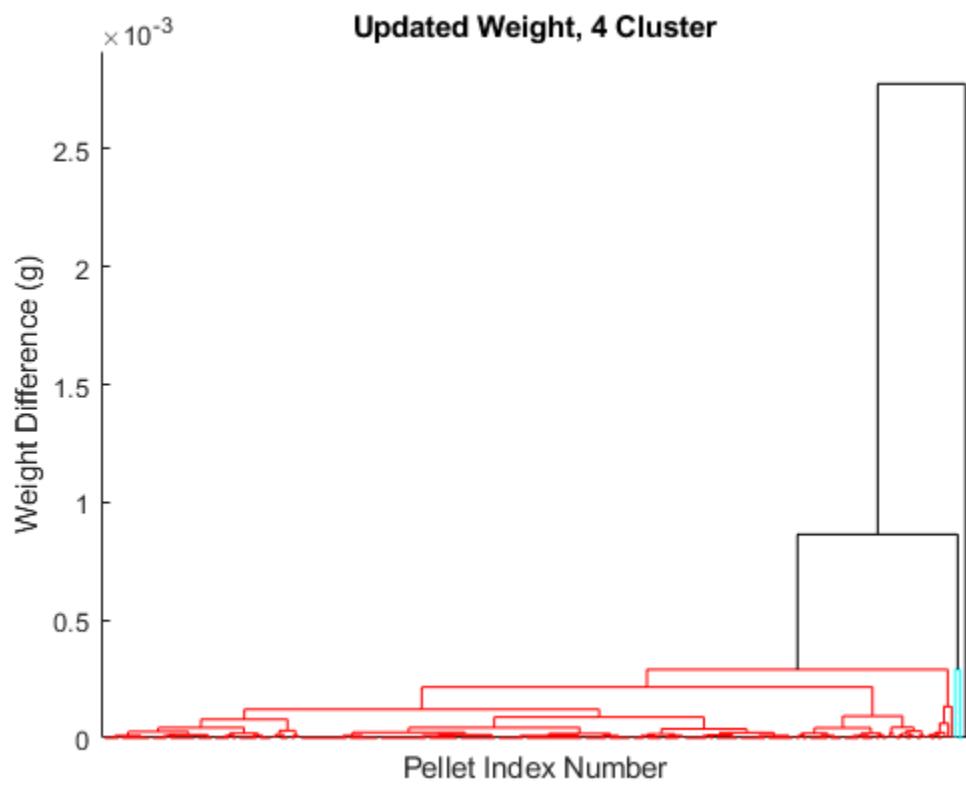
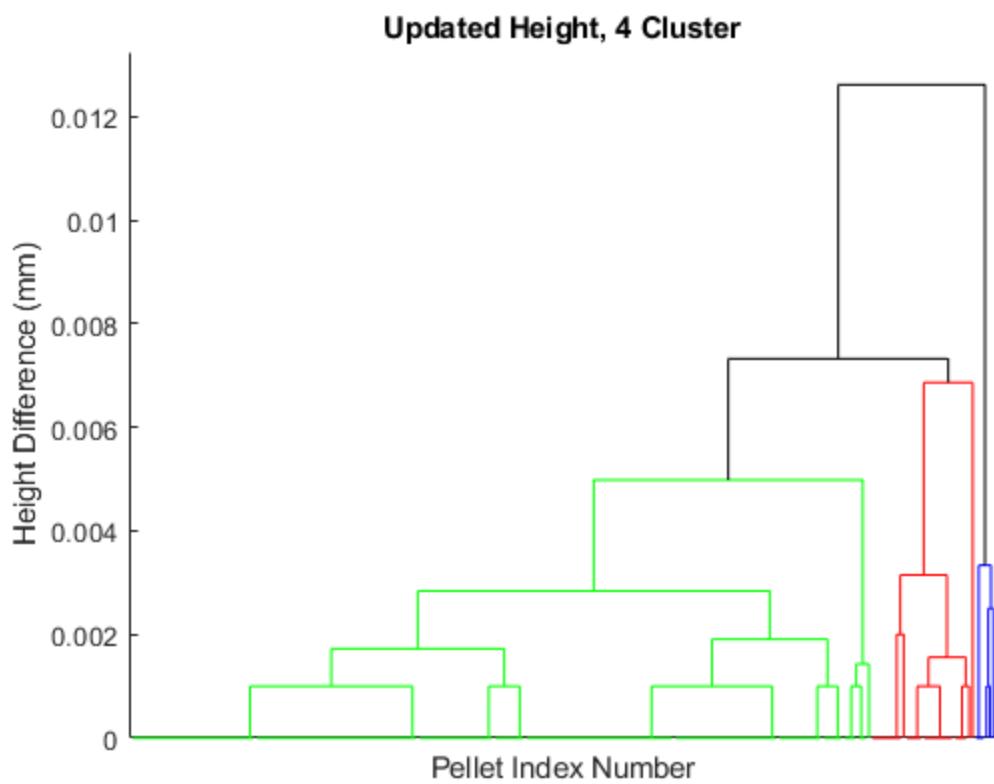
0	1	0	0	0
0	0	0	0	2
7	0	1	0	0
<b>43</b>	<b>49</b>	<b>49</b>	<b>50</b>	<b>47</b>
0	0	0	0	1

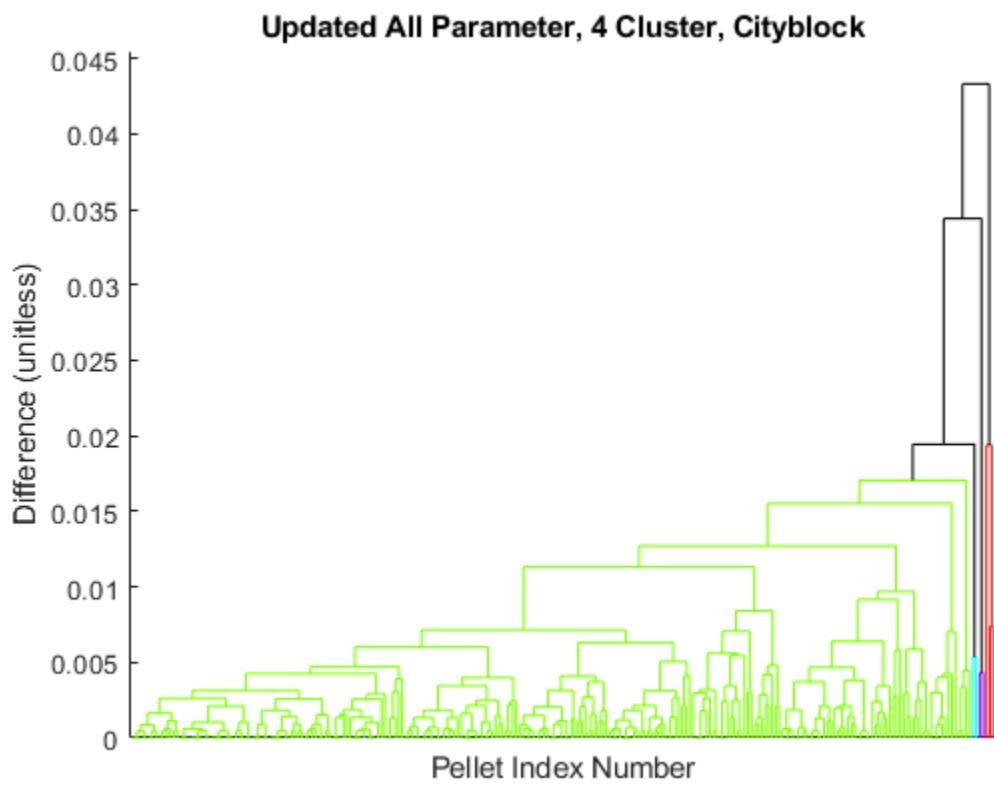
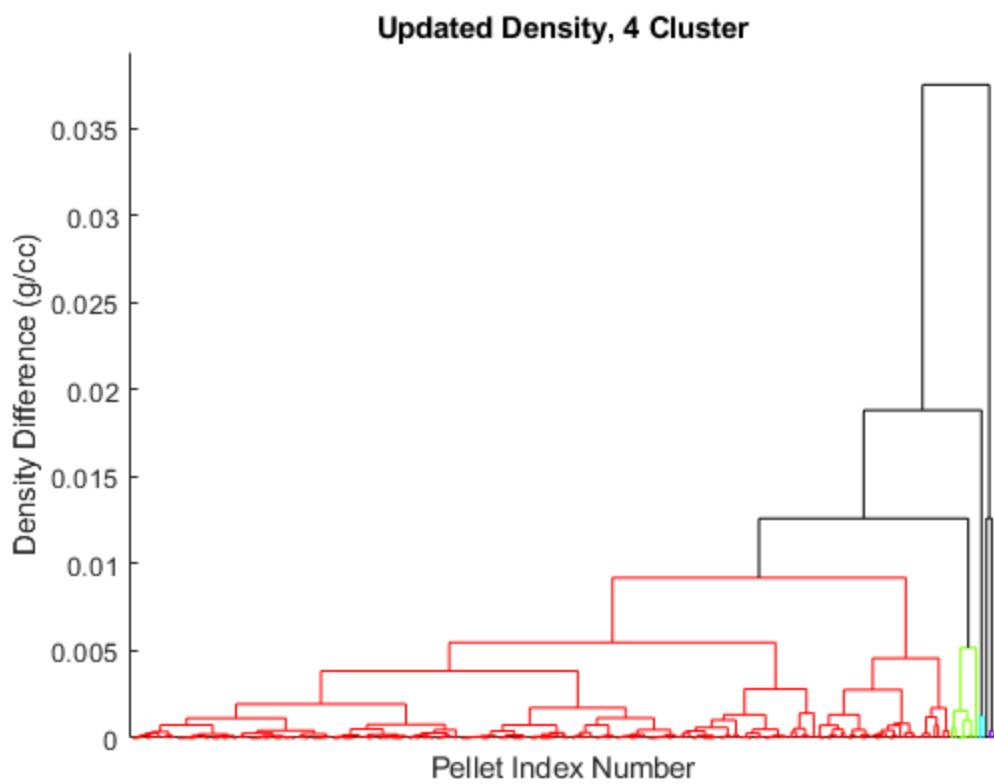
*UpdatedDensitySort5* =

7	0	1	0	0
<b>42</b>	<b>49</b>	<b>49</b>	<b>50</b>	<b>47</b>
0	1	0	0	0
0	0	0	0	2
1	0	0	0	1

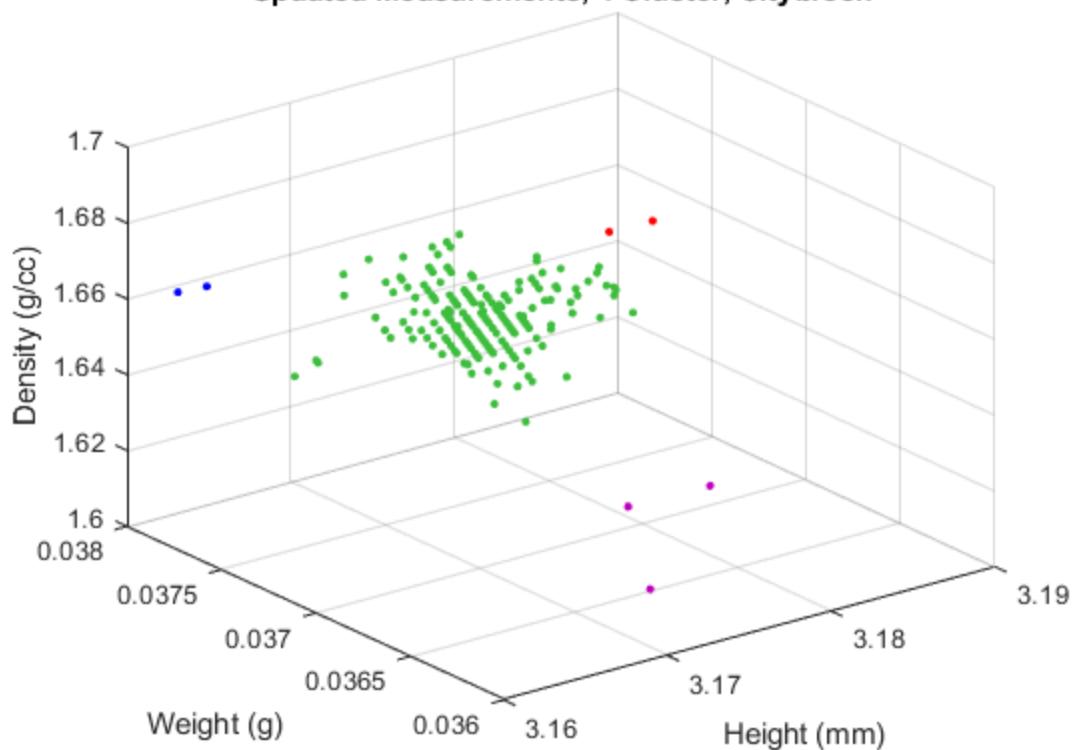
*UpdatedAllParaSort5* =

0	1	0	0	0
0	0	0	0	2
0	0	0	0	2
<b>49</b>	<b>49</b>	<b>50</b>	<b>50</b>	<b>45</b>
1	0	0	0	1





**Updated Measurements, 4 Cluster, Cityblock**



**Updated Height, 5 Cluster**

